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16. ABSTRACT

This report describes the methodology and the specific conversion factros used for the heavy-duty gasoline and diesel powered vehicles for the model years 1962 through 2000.

Heavy-duty emission factors are used by MOBILE4, a computer program that determines emission inventories in various localities.

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Technical Report

Heavy-Duty Vehicle Emission Conversion Factors II 1962-2000

By

Paul A. Machiele

October, 1988

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Standards Development and Support Branch
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I. Introduction

MOBILE4 is a computer program that generates in-use emission factors by calendar year, ambient temperature and driving situation in units of grams per mile (g/mi) for all vehicle classes, which are then used to determine emissions inventories in various localities. Because urban areas are modelled almost exclusively, urban emission factors are desired and generated here. Since heavy-duty engine testing provides emissions in terms of grams per brake horsepower-hour (g/BHP-hr), brake horsepower-hour per mile (BHP-hr/mi) conversion factors are needed to convert the brake-specific emission levels into the necessary mile-specific (g/mi) units, as illustrated below:

Emission Factor = Emission Test Data x Conversion Factor

$$\frac{g}{mi} = \frac{g}{BHP\text{-}hr} \times \frac{BHP\text{-}hr}{mi}$$

This technical report outlines the methodology used to determine these conversion factors, as well as providing the conversion factors for heavy-duty gasoline and diesel engines for the model years 1962 through 2000 (see Table 1). Since this report is for the most part an update of the previous conversion factor analysis performed for MOBILE3, also shown are the conversion factors as calculated in that analysis.[1] As can be seen, there is a distinct decrease in the diesel fleet average conversion factors for recent and future years over and above that which was predicted in the MOBILE3 conversion factor analysis. Although fuel density, fuel economy, and other differences also have an effect, the largest part of this decrease is attributable to greater sales growth in the lighter diesel classes than had previously been predicted. A similar decrease in conversion factors can also be seen in the gasoline fleet since there is a smaller fraction of gasoline vehicles in the heavier classes than had been predicted. Overall, the heavy-duty fleet is probably not getting that much lighter, but the dieselization of the fleet has caused both diesel and gasoline fleet average conversion factors to decrease. The steadiness of the conversion factor values in future years is attributable to very small non-engine related fuel economy improvements, and to the nearing of maximum market penetration of diesel vehicles in the lighter classes.

The BHP-hr/mi conversion factors were calculated from brake-specific fuel consumption (BSFC), fuel density, and fuel economy (all of which can be measured), because it is difficult to measure BHP-hr/mi directly. The equation used was:

CF (BHP-hr/mi) = ρ (lb/gal) / (BSFC (lb/BHP-hr) * FE (mi/gal))

Table 1

Fleet-Average
Conversion Factors (BHP-hr/mi)

	Gasoline		Diesel	
Year	MOBILE3	MOBILE4	MOBILE3	MOBILE4
1962	1.29	1.55	2.74	2.85
1963	1.31	1.54	2.74	2.86
1964	1.32	1.54	2.73	2.87
1965	1.33	1.53	2.72	2.89
1966	1.35	1.52	2.76	2.90
1967	1.36	1.52	2.82	2.96
1968	1.37	1.50	2.88	3.00
1969	1.37	1.48	2.94	3.07
1970	1.37	1.45	3.00	3.10
1971	1.37	1.45	3.08	3.16
1972	1.37	1.44	3.15	3.20
1973	1.34	1.42	3.19	3.19
1974	1.31	1.42	3.23	3.21
1975	1.28	1.31	3.27	3.15
1976	1.20	1.24	3.23	3.18
1977	1.12	1.07	3.19	3.25
1978	1.08	1.06	3.07	3.19
1979	1.05	1.02	2.95	3.00
1980	1.01	0.96	2.84	2.72
1981	0.98	0.94	2.72	2.70
1982	0.95	0.91	2.60	2.38
1983	0.95	0.88	2.56	2.28
1984	0.95	0.91	2.51	2.41
1985	0.96	0.90	2.47	2.20
1986	0.97	0.89	2.43	2.21
1987	0.97	0.90	2.38	2.17
1988	0.97	0.90	2.38	2.13
1989	0.96	0.89	2.37	2.10
1990	0.96	0.89	2.36	2.07
1991	0.96	0.89	2.35	2.05
1992	0.95	0.89	2.34	2.03
1993	0.94	0.89	2.33	2.03
1994	0.94	0.89	2.33	2.03
1995	0.93	0.89	2.32	2.04
1996	0.92	0.89	2.31	2.04
1997	0.92	0.89	2.31	2.04
1998	0.92	0.89	2.31	2.04
1989	0.92	0.88	2.31	2.04
2000	0.92	0.88	2.31	2.03

The emission conversion factors were first calculated by gross vehicle weight (GVW) class for both gasoline and diesel powered vehicles, as both BSFC and fuel economy vary with gross vehicle weight and fuel type. Diesel and gasoline fleet-average conversion factors were then calculated using the appropriate vehicle miles traveled (VMT) weighting of the class-specific conversion factors. Gasoline and diesel fleet-average conversion factors were derived separately because MOBILE4 treats them separately.

Estimates of historic BSFC and fuel economy figures were limited to 1982 and earlier model years due to our dependence for in-use fuel economy estimates on the U.S. Census Bureau's Truck In-use Survey (TIUS), which is taken every five years. Thus, historic class-specific conversion factors for the years 1982 and earlier may be calculated using the equation given above. Future (i.e., post-1982) conversion factors will not be affected by changes in BSFC, as any decrease in BSFC will be cancelled out by a corresponding increase in fuel economy. As fuel density changes little over time and can be assumed constant, the only factors affecting future heavy-duty vehicle conversion factors are future non-engine-related fuel economy improvements. Future class-specific conversion factors are thus estimated by reducing the 1982 conversion factors in proportion to the projected increase in fuel economy due to non-engine-related factors. For this reason, historic and future conversion factors are calculated separately; the former using the above equation, and the latter using projected non-engine-related fuel economy improvements applied to the 1982 conversion factors.

This report begins with a description of the fuel densities, engine BSFCs, and vehicle fuel economies used to calculate the historic class-specific conversion factors. Following this discussion, future non-engine-related fuel economy improvements are analyzed and their application to historic class-specific conversion factors described. The VMT-weighting methodology used to obtain the diesel and gasoline fleet-average conversion factors is then presented and each factor used in the VMT weighting process described.

II. Historic Class-Specific Conversion Factors

As in the previous conversion factors analysis, historic class-specific conversion factors were calculated using three basic parameters: fuel density, brake-specific fuel consumption, and fuel economy, as detailed above. However, for the previous analysis, historic data was limited by the 1977 TIUS, and as a result historic conversion factors ended at 1977. For this analysis the 1982 TIUS is the source for historical fuel economy estimates, and thus, historical conversion factors end with 1982. The methods used to determine the fuel density, brake specific fuel consumption, and fuel economy are detailed in the following paragraphs.

A. Fuel Density

The gasoline and diesel fuel densities used in the calculation of historic conversion factors were 6.09 and 7.11 pounds (lbs) per gallon, respectively. The value for gasoline, as seen in Table 2, was taken from an average over the 1982 to 1985 period of both summer and winter fuel density data presented in the NIPER gasoline surveys.[2] The diesel fuel density also shown in Table 2 was taken from an average over the same period of data presented in the MVMA fuel surveys.[3] The values used are very similar to those used in the past for MOBILE3.[1] The fuel density values are not changed for each year even though the necessary information exists to do so, since both MOBILE4 and this conversion factor analysis are model year specific, while the changes in fuel density are a calendar year phenomenon. It may be possible to take the calendar year changes in fuel density into account with more extensive programming, but the benefits of incorporating these small changes (a less than one percent increase in accuracy) are outweighed by the complexity of the task to perform such work.

B. Brake-Specific Fuel Consumption

The class-specific gasoline and diesel BSFCs for the 1962 to 1977 period were taken directly from the conversion factor analysis done for MOBILE3.[1] Since manufacturers are no longer required to provide this information as part of the engine certification process, more recent engine BSFC data was not readily available. As a result, the major manufacturers were contacted by phone in June, 1987, and asked to provide information on the BSFCs of their current (1987) models. The manufacturers provided the necessary information, but many of them also asked that the individual engine data not be presented in this report. As a result, it is not shown here. The BSFC information was then sales weighted to achieve class-specific BSFC values for 1987. These values in turn were used in conjunction with the 1977 and previous values to interpolate the values for the 1978 to 1982 period. Changes in BSFC were apparently rather small over this period, indicating little improvement in heavy-duty engine efficiency.

BSFC values for transit buses were obtained by assuming that the majority of buses in the past used Detroit Diesel Allison (DDA) 6V-71N engines, which have been progressively replaced with the DDA 6V-92TA engines. Some of EPA's in-house test data over the bus central business district cycle revealed that the 6V-71N engine obtained a BSFC of 0.557 lb/BHP-hr, while the 6V-92TA obtained approximately 0.47 lb/BHP-hr over the same cycle. By using estimates of annual sales of these two engines provided by DDA, the model year specific BSFCs for the class could be estimated. The BSFC values for commercial buses utilized the same methodology with the exception that the

Table 2

Historical Fuel Density (lb/gal) [2,3]

Year	Gasoline	Diesel
82	6.107	7.098
83	6.093	7.131
84	6.083	7.102
85	6.085	7.114
Average	6.09	7.11
MOBILE3	6.16	7.07

transient cycle was chosen to be more representative for this class of bus. This resulted in somewhat lower BSFCs since the 6V-71N has a BSFC of approximately 0.529 lb/BHP-hr over the transient cycle, and the 6V-92TA a BSFC of approximately 0.46 lb/BHP-hr over the transient cycle. The BSFC values for the school buses were calculated by sales weighting the class specific truck data based on the class specific sales of school buses from MVMA sales data.[4] The BSFC values for all classes for the years 1962 through 1987 are shown in Table 3.

C. Fuel Economy

The model year specific fuel economies for all truck classes except for Class 2B were obtained by smoothing the data in the analysis of the 1982 TIUS done by Energy and Environmental Analysis Inc. (EEA).[5] The 1982 TIUS did not distinguish Class 2B from Class 2 as a whole. Only Class 2B fuel economy is pertinent to heavy-duty vehicle emissions, as Class 2A vehicles are treated as light-duty trucks by EPA regulations, and in MOBILE4. In order to estimate Class 2B fuel economy it was assumed, as in the MOBILE3 conversion factor analysis, that Class 2B fuel economy is 10 percent less than Class 2A fuel economy due to increased vehicle size. Diesel and gasoline fuel economies were determined separately by assuming that the ratio of Class 2B diesel BSFC to gasoline BSFC also represents the ratio of their fuel economies.

Commercial and school bus fuel economies were taken from the Federal Highway Administration (FHA) Highway Statistics.[6] These are fleet values instead of model year specific values, but they represent the best data available, and these values do not change significantly with time. As a result, they are thought to be fairly representative of the model year fuel economies. Transit bus values were then estimated as 85.8 percent of the commercial bus value, based on 1978 through 1983 data from the American Public Transit Association (APTA) fact book.[7] The transit and commercial bus fleet fuel economies were divided into gasoline and diesel by assuming that the Class 8A truck diesel advantage factors were applicable. The school bus fuel economies from the FHA data were broken up into gasoline and diesel by assuming that the diesel buses obtain 30 percent better fuel economy than their gasoline counterparts. This assumption was based on a review of 1980 through 1982 diesel advantage factors for Class 5 through Class 7 trucks, the engines of which make up the school bus market. All of these fuel economies are shown in Table 4.

The fuel economies presented in EEA's analysis of the TIUS are national fuel economies (i.e., the result of a combination of rural and urban driving).[5] MOBILE4, however, is primarily used to model urban emissions, and as a result requires urban fuel economy values. The conversion factor analysis done for MOBILE3 looked at this issue. Although some information

Table 3

Historic BSFC (lb/BHP-hr)

Year	Class2B	Class3-5	Class6	Class7	Class8A	Class8B	Transit	Commercial	School
DIESEL									
62	.54	.51	.50	.49	.49	.49	.557	.529	*
63	.54	.51	.50	.49	.49	.49	.557	.529	*
64	.54	.51	.50	.49	.49	.49	.557	.529	*
65	.54	.51	.50	.49	.49	.49	.557	.529	*
66	.54	.51	.50	.49	.49	.49	.557	.529	*
67	.54	.51	.50	.48	.48	.48	.557	.529	*
68	.54	.51	.50	.48	.48	.48	.557	.529	*
69	.54	.51	.49	.48	.47	.47	.557	.529	*
70	.54	.51	.49	.47	.47	.47	.557	.529	*
71	.54	.51	.48	.47	.46	.46	.557	.529	*
72	.54	.51	.47	.47	.46	.46	.557	.529	*
73	.54	.51	.47	.46	.46	.46	.557	.529	*
74	.54	.51	.46	.46	.45	.45	.557	.529	*
75	.54	.51	.46	.46	.45	.45	.557	.529	*
76	.54	.51	.46	.46	.44	.44	.553	.526	.452
77	.54	.51	.45	.45	.43	.43	.548	.522	.452
78	.54	.51	.45	.45	.43	.43	.544	.519	.450
79	.54	.51	.45	.45	.43	.43	.540	.515	.448
80	.54	.51	.45	.45	.43	.42	.535	.512	.447
81	.54	.51	.45	.44	.42	.42	.525	.503	.446
82	.54	.51	.45	.44	.42	.42	.515	.496	.445
83**	.54	.51	.45	.44	.42	.41	.505	.488	.446
84**	.54	.51	.45	.44	.41	.41	.498	.482	.445
85**	.54	.51	.45	.44	.41	.40	.492	.477	.445
86**	.54	.51	.45	.44	.41	.40	.485	.472	.444
87**	.54	.51	.45	.44	.41	.39	.479	.467	.444
GASOLINE									
62-78	.70	.70	.70	.70	.70	.70	.70	.70	.70
79	.70	.70	.70	.70	.70	*	.70	.70	.699
80	.69	.69	.70	.70	.69	*	.70	.70	.697
81	.69	.69	.69	.69	.69	*	*	*	.694
82	.68	.68	.69	.69	.68	*	*	*	.691
83**	.64	.64	.69	.68	.66	*	*	*	.686
84**	.63	.63	.68	.67	.64	*	*	*	.678
85**	.63	.63	.67	.66	.64	*	*	*	.670
86**	.62	.62	.66	.65	.63	*	*	*	.664
87**	.62	.62	.66	.65	.63	*	*	*	.660

* No Sales

** Used only to determine the 1978-1982 values

Table 4

FUEL ECONOMY (MPG)

Year	Class2B	Class3-5	Class6	Class7	Class8A	Class8B	Transit	Commercial	School
DIESEL VEHICLES									
62	*	6.45	5.80	5.60	5.10	4.72	4.27	4.97	*
63	*	6.45	5.80	5.60	5.10	4.72	4.27	4.97	*
64	*	6.45	5.80	5.60	5.10	4.72	4.27	4.97	*
65	*	6.45	5.80	5.60	5.10	4.72	4.27	4.97	*
66	*	6.45	5.80	5.60	5.10	4.72	4.27	4.97	*
67	*	6.45	5.80	5.60	5.10	4.72	4.27	4.97	*
68	*	6.45	5.80	5.60	5.10	4.72	4.20	4.89	*
69	*	6.45	5.80	5.60	5.10	4.72	4.02	4.69	*
70	*	6.45	5.80	5.60	5.10	4.72	3.98	4.62	*
71	*	6.45	5.80	5.60	5.10	4.72	4.06	4.73	*
72	*	6.45	5.80	5.60	5.10	4.72	3.82	4.45	*
73	*	6.45	5.80	5.60	5.10	4.72	4.07	4.74	*
74	*	6.94	6.06	5.57	5.09	4.75	4.31	5.03	*
75	*	7.42	6.33	5.56	5.10	4.79	4.15	4.84	*
76	*	7.91	6.60	5.60	5.12	4.82	4.38	5.11	*
77	*	*	6.86	5.74	5.20	4.86	4.34	5.07	9.54
78	*	*	7.13	6.04	5.29	4.92	4.32	5.04	9.55
79	*	*	7.40	6.55	5.36	5.00	4.35	5.07	9.56
80	*	*	7.67	7.01	5.40	5.08	4.33	5.04	9.90
81	13.98	*	7.93	7.25	5.45	5.20	4.27	4.98	9.88
82	14.26	*	8.20	7.37	5.48	5.37	4.26	4.96	9.87
GASOLINE VEHICLES									
62	9.06	6.43	5.75	4.58	4.24	3.35	3.55	4.13	7.08
63	9.06	6.43	5.75	4.58	4.24	3.35	3.55	4.13	7.08
64	9.06	6.43	5.75	4.58	4.24	3.35	3.55	4.13	7.08
65	9.06	6.43	5.75	4.58	4.24	3.35	3.55	4.13	7.08
66	9.06	6.43	5.75	4.58	4.24	3.35	3.55	4.13	7.08
67	9.06	6.43	5.75	4.58	4.24	3.35	3.55	4.13	7.08
68	9.06	6.43	5.75	4.58	4.24	3.35	3.41	4.06	6.99
69	9.06	6.43	5.75	4.58	4.24	3.35	3.34	3.89	7.00
70	9.06	6.43	5.75	4.58	4.24	3.35	3.31	3.85	7.00
71	9.06	6.43	5.75	4.58	4.24	3.35	3.38	3.93	7.00
72	9.06	6.43	5.75	4.58	4.24	3.35	3.18	3.70	7.37
73	9.06	6.43	5.75	4.58	4.24	3.35	3.39	3.94	7.36
74	9.28	6.45	5.65	4.60	4.37	3.50	3.70	4.31	7.36
75	9.49	6.47	5.60	4.61	4.49	3.64	3.66	4.26	7.31
76	9.71	6.49	5.61	4.63	4.41	3.79	3.77	4.40	7.34
77	9.92	6.51	5.66	4.67	4.73	*	3.95	4.61	7.34
78	10.14	6.53	5.73	4.80	4.86	*	3.98	4.64	7.35
79	10.35	6.55	5.83	4.97	4.98	*	4.04	4.71	7.35
80	10.57	6.57	5.99	5.10	5.10	*	4.08	4.76	7.62
81	10.78	6.59	6.22	5.16	5.22	*	*	*	7.60
82	11.00	6.61	6.50	5.15	5.35	*	*	*	7.59

* No Sales

suggested that urban fuel economy should be lower than rural fuel economy, other information suggested that due to lower vehicle loads in urban areas, the fuel economy in an urban area may be very similar to that in a rural area. Because of this, and the fact that reliable data on this topic was limited, it was decided that the nationwide fuel economy values available from the TIUS adequately represented the urban fuel economy. Since no further work in this area has been done, this analysis for MOBILE4 also will assume that the TIUS fuel economy values are representative of urban driving.

Fuel economy values estimated using the 1977 TIUS and used in the MOBILE3 conversion factor analysis are shown in Table A-1. With the obvious exception of buses, the historical fuel economies estimated by the 1982 TIUS and used in this analysis tend to be significantly lower. (Bus fuel economy in both analyses was not determined using the TIUS, and as a result is not subject to the same influences as truck fuel economies.) By 1982, however, the historical estimates from the 1982 TIUS compare fairly well with the predictions based on the 1977 TIUS as found in the MOBILE3 analysis. This seems to suggest that contrary to EPA's assumption, the fuel economy of a given model year fleet does change significantly over time. At present there is not enough information to support this, but it should be considered in any further conversion factor analyses. Incorporation of such an effect will, however, require modification of MOBILE4 in order to incorporate calendar year changes.

D. Summary of Historic Conversion Factors

In summary, historic class-specific conversion factors were based on: fuel densities from NIPER and MVMA fuel surveys,[2,3] BSFCs from the MOBILE3 conversion factor analysis and manufacturer information,[1] and fuel economies from the 1982 TIUS for trucks and the FHA Highway Statistics for buses.[5,6] These gasoline and diesel class-specific conversion factors are listed in Tables 5 and 6. The class-specific conversion factors are then used as the basis for the prediction of future class-specific conversion factors, as described below.

The historic values were determined in the same manner as the pre-1978 conversion factors in the MOBILE3 analysis and shown in Table A-1, but vary due to differences in the fuel density, BSFC, and fuel economy inputs discussed earlier. In particular, the pre-1978 diesel class specific conversion factors in this analysis tend to be significantly higher than in the previous analysis due to differences in historic fuel economy estimates.

TABLE 5

DIESEL CLASS-SPECIFIC CONVERSION FACTORS (BHP-hr/mi)

MODEL YEAR	CLASS 2B	CLASS 3	CLASS 4	CLASS 5	CLASS 6	CLASS 7	CLASS 8A	CLASS 8B	TRANSIT	COMMERCIAL	SCHOOL
62	0.000	2.161	2.161	2.161	2.452	2.591	2.845	3.074	2.989	2.704	0.000
63	0.000	2.161	2.161	2.161	2.452	2.591	2.845	3.074	2.989	2.704	0.000
64	0.000	2.161	2.161	2.161	2.452	2.591	2.845	3.074	2.989	2.704	0.000
65	0.000	2.161	2.161	2.161	2.452	2.591	2.845	3.074	2.989	2.704	0.000
66	0.000	2.161	2.161	2.161	2.452	2.591	2.845	3.074	2.989	2.704	0.000
67	0.000	2.161	2.161	2.161	2.452	2.645	2.904	3.138	2.989	2.704	0.000
68	0.000	2.161	2.161	2.161	2.452	2.645	2.904	3.138	3.113	2.812	0.000
69	0.000	2.161	2.161	2.161	2.502	2.645	2.966	3.205	3.175	2.866	0.000
70	0.000	2.161	2.161	2.161	2.502	2.701	2.966	3.205	3.207	2.909	0.000
71	0.000	2.161	2.161	2.161	2.554	2.701	3.031	3.275	3.144	2.842	0.000
72	0.000	2.161	2.161	2.161	2.608	2.701	3.031	3.275	3.342	3.020	0.000
73	0.000	2.161	2.161	2.161	2.608	2.760	3.031	3.275	3.136	2.836	0.000
74	0.000	2.009	2.009	2.009	2.551	2.775	3.104	3.326	2.962	2.672	0.000
75	0.000	1.879	1.879	1.879	2.442	2.780	3.098	3.299	3.076	2.777	0.000
76	0.000	1.762	1.762	1.762	2.342	2.760	3.156	3.353	2.935	2.645	0.000
77	0.000	0.000	0.000	0.000	2.303	2.753	3.180	3.402	2.990	2.687	0.000
78	0.000	0.000	0.000	0.000	2.216	2.616	3.126	3.361	3.025	2.718	0.000
79	0.000	0.000	0.000	0.000	2.135	2.412	3.085	3.307	3.027	2.723	1.653
80	0.000	0.000	0.000	0.000	2.060	2.254	3.062	3.332	3.069	2.755	1.603
81	0.942	0.000	0.000	0.000	1.992	2.229	3.106	3.255	3.172	2.838	1.610
82	0.923	0.000	0.000	0.000	1.927	2.193	3.089	3.152	3.241	2.890	1.615
83	0.923	0.000	0.000	0.000	1.911	2.176	3.059	3.150	3.241	2.890	1.615
84	0.922	0.000	0.000	0.000	1.892	2.159	3.035	3.141	3.241	2.890	1.615
85	0.921	0.000	0.000	0.000	1.877	2.143	3.010	3.138	3.241	2.890	1.615
86	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
87	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
88	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
89	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
90	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
91	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
92	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
93	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
94	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
95	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
96	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
97	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
98	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
99	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615
2000	0.919	0.000	0.000	0.000	1.865	2.127	2.987	3.129	3.241	2.890	1.615

TABLE 6

GASOLINE CLASS-SPECIFIC CONVERSION FACTORS (BHP-hr/mi)

MODEL YEAR	CLASS 2B	CLASS 3	CLASS 4	CLASS 5	CLASS 6	CLASS 7	CLASS 8A	CLASS 8B	TRANSIT	COMMERCIAL	SCHOOL
62	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.451	2.106	1.229
63	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.451	2.106	1.229
64	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.451	2.106	1.229
65	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.451	2.106	1.229
66	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.451	2.106	1.229
67	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.451	2.106	1.229
68	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.552	2.189	1.245
69	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.603	2.231	1.243
70	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.629	2.265	1.243
71	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.577	2.212	1.243
72	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.739	2.352	1.180
73	0.960	1.353	1.353	1.353	1.513	1.900	2.052	2.597	2.571	2.208	1.182
74	0.938	1.349	1.349	1.349	1.540	1.891	1.991	2.486	2.351	2.015	1.182
75	0.917	1.345	1.345	1.345	1.554	1.887	1.938	2.390	2.381	2.042	1.190
76	0.896	1.341	1.341	1.341	1.551	1.879	1.973	2.296	2.306	1.977	1.185
77	0.877	1.336	1.336	1.336	1.537	1.863	1.839	0.000	2.204	1.886	1.185
78	0.858	1.332	1.332	1.332	1.518	1.813	1.790	0.000	2.192	1.879	1.184
79	0.841	1.328	1.328	1.328	1.492	1.751	1.747	0.000	2.153	1.847	1.185
80	0.835	1.343	1.343	1.343	1.452	1.706	1.731	0.000	2.127	1.828	1.147
81	0.819	1.339	1.339	1.339	1.419	1.710	1.691	0.000	0.000	0.000	1.155
82	0.814	1.355	1.355	1.355	1.358	1.714	1.674	0.000	0.000	0.000	1.161
83	0.813	1.354	1.354	1.353	1.347	1.702	1.662	0.000	0.000	0.000	1.161
84	0.813	1.353	1.353	1.351	1.337	1.692	1.651	0.000	0.000	0.000	1.161
85	0.811	1.350	1.351	1.347	1.327	1.680	1.639	0.000	0.000	0.000	1.161
86	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
87	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
88	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
89	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
90	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
91	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
92	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
93	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
94	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
95	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
96	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
97	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
98	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
99	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161
2000	0.809	1.346	1.348	1.342	1.317	1.668	1.627	0.000	0.000	0.000	1.161

One other difference between the MOBILE3 conversion factor analysis and this analysis is that conversion factors for the period of 1978-1982 are now derived using historic data whereas previous estimates were predicted from the available data (in a manner similar to that used in the following section for post-82 conversion factors). As shown in Table 7, the 1982 TIUS typically resulted in much greater increases in non-engine related fuel economy improvements for the 1977 to 1982 period than had been predicted by the MOBILE3 conversion factor analysis. The result of this is that by 1982, the class specific conversion factors found in Tables 5 and 6 compare fairly well (depending on vehicle class) with those predicted in the MOBILE3 conversion factor analysis shown in Table A-2. (Due to differences in the method used to estimate fuel economy, as discussed earlier, this does not hold true for buses.)

III. Future Class Specific Conversion Factors

Post-1982 class-specific gasoline and diesel conversion factors (see Tables 5 and 6) were estimated using 1982 class-specific conversion factors and projected future non-engine-related fuel economy improvements. Engine-related fuel economy improvements affect both BSFC and fuel economy (BSFC decreases as fuel economy increases) and, thus, do not affect the conversion factor. Future conversion factors are calculated by dividing the historic conversion factor by 1.0 plus the non-engine-related fuel economy improvement (as a fraction) that is predicted to occur between the 1982 base year and the year in question.

A. Future Non-Engine Related Fuel Economy Developments

For the MOBILE3 conversion factor analysis several fairly detailed studies of future non-engine-related fuel economy improvements were conducted and submitted to EPA. Most of the information used economic and cost/benefit analysis to project the penetration of the fuel-economy improving devices into the future. The data and estimates were reviewed and those which seemed reasonable were used. Non-engine related fuel economy improvements accepted for the analysis included the use of weight reduction, radial tires, aerodynamic add-on devices, drivetrain lubricants, improved fan drives, overdrive, electronic transmission control, and speed control devices.

Since that time little new information has become available on which to base new estimates. Some new information was available concerning the use of radial tires and aerodynamic devices, but it was of sufficient detail only to show that the values used in the MOBILE3 analysis were reasonable.[8,9]. Some information on the penetration of fuel economy improvement devices from a survey performed by the University of Michigan Transportation Research Institute

Table 7

Percent Increase in Non-Engine-Related
Fuel Economy From 1977 to 1982
(Ratio of 1982 to 1977 conversion factors)

	MOBILE3		MOBILE4*	
Class	Gas	Diesel	Gas	Diesel
2B	2.9	3.4	7.2	NA
3	NA	NA	1.4	NA
4	NA	NA	1.4	NA
5	NA	NA	1.4	NA
6	2.3	0.3	11.6	16.3
7	2.1	0.4	8.0	20.3
8A	1.8	0.4	9.0	2.9
8B	NA	6.0	NA	7.3
Transit	NA	0.4	NA	-8.4
Commercial	NA	0.4	NA	-7.5
School	NA	0.4	2.0	NA

* Assumes BSFC estimates are accurate

(UMTRI) was provided by the Motor Vehicle Manufacturers Association (MVMA) and the Engine Manufacturers Association (EMA) in a meeting held March 7, 1988.[10] Unfortunately, it was not in a form which enabled it to be incorporated into this analysis. UMTRI subsequently provided the information to EPA in a more usable form.[11] However, due to the small effect expected to result from its incorporation, and a number of questions as to how it should be used, it has not been incorporated into the new conversion factor analysis at this time.

One such question involves how well a vehicle owner's perception of his vehicle's design reflects reality when it is often based on sales promotions. For example, even though a vehicle is marketed as being aerodynamic, how aerodynamic it really is when compared to other vehicles is not addressed. A number of truck owners responded affirmatively to the question of whether their vehicle had an aerodynamic cab design even though their trucks were from the pre-1980 period, a period known for non-aerodynamic designs. A second question involves how well the effectiveness of a vehicle owner's fuel saving device compares with the effectiveness attributed to that device by independent research when the designs can be significantly different. For some categories such as radial tires, the difference is probably rather small, but for aerodynamic devices, or fuel efficient lubricants, the difference can be extremely large. A third question involves how gasoline vehicles should be treated since only diesel vehicles were surveyed. Diesel vehicles tend to accumulate more miles in a given year, and are driven more in line-haul applications. As a result, the use of fuel saving devices tends to be more cost effective for them than for gasoline vehicles. A fourth question is how to project the penetration rates into the future where they are applied. In addition to other problems associated with extrapolations, the drop in fuel prices in late 1985 caused the fuel economy devices to be less cost effective and therefore less likely to be utilized. An additional difficulty with incorporating the information is how to treat fuel saving devices which appear to be a calendar year phenomena rather than a model year phenomena. MOBILE4 currently has the capacity to treat only model-year specific changes. The time required to make the necessary changes to incorporate calendar year effects as well goes beyond the required deadline for completion of MOBILE4.

As a result of the difficulties with incorporating the UMTRI information, the penetration rates and fuel economy improvements assumed in the MOBILE3 conversion factor analysis were accepted for use in MOBILE4. The penetration rates determined in the NIPER survey are typically slightly higher than the MOBILE3 projections, however, this seems logical since only diesel vehicles were surveyed, and the MOBILE3 penetration rates are for both gasoline and diesel vehicles. As a result

the differences between the UMTRI data and the information used in the MOBILE3 analysis may be smaller than would appear. The UMTRI information limited to those devices incorporated in the MOBILE3 analysis is summarized in Appendix B.

Due to the drastic change in the fuel price structure which occurred late in 1985, many of the fuel economy improvements are no longer economically attractive for many of the vehicle applications. As a result, the projections of device penetration into the truck market beyond 1986 are no longer valid. For this reason, the MOBILE3 projections were only used for the 1982 to 1986 time frame, and no non-engine-related fuel economy improvements were assumed beyond 1986. As this approach was presented at the MOBILE4 workshop held in Ann Arbor on November 10, 1987, and no data other than the UMTRI survey was forthcoming to show otherwise, no non-engine-related fuel economy improvements are projected beyond 1986.

The estimates of fuel economy improvements here as for MOBILE3 were derived according to GVW class (Classes IIb-IV or light heavy-duty vehicles (LHDVs), Classes VI-VIIIa or medium heavy-duty vehicles (MHDVs), and Class VIIIb or heavy heavy-duty vehicles (HHDVs)) as specific improvements will affect each class differently. These improvements are all detailed and referenced in Tables 8 through 10, and the net fuel economy improvements shown in Table 11. Although the market penetration rates of the fuel economy improvement devices in Tables 8 through 10 were assumed to affect the fleet as a whole, improvement devices were assumed to be applied first in the long-range applications of each class where they would be most economically attractive, then the short-range, and then the local applications. As a result of differences in the distribution of gasoline and diesel vehicles in long-range, short-range, and local usage categories, the overall fuel economy improvements as seen in Table 11 are different for gasoline vehicles than for diesel vehicles. Explanations of the selection of the penetration rates and associated fuel economy improvements associated with each device exist in the MOBILE3 conversion factor analysis and are not repeated here.[1]

B. Application of Non-Engine-Related Fuel Economy Improvements

Since a fuel economy saving device will typically be applied where it is most cost effective, the above non-engine-related fuel economy improvements were applied first in the high-mileage, long-range applications, second in the short-range applications, and last of all in the lowest mileage, local applications. The breakdown of trucks into these usage categories as seen in Table 12 is based on data in the 1982 TIUS.[5] Since the estimates of fleet penetration were not fuel specific, the only differences between the net

Table 8

Class IIB-IV--Light Heavy-Duty Vehicles
Future Non-Engine Related Fuel Economy Improvements

Weight Reduction

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	6.6	50	50	50	50	50	50
MOBILE4	6.6	50	50	50	50	50	50

Radials & Advanced Radials

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	1.4 (radial)	55	58	61	64	67	90
MOBILE4	1.4	55	58	61	64	67	67
MOBILE3[1]	0.0 (adv. rad)	0	0	0	0	0	0
MOBILE4	0.0	0	0	0	0	0	0

Aerodynamics (add-on) None

Aerodynamics (body)

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	0	0	0	0	0	0	0
MOBILE4	0	0	0	0	0	0	0

Drivetrain Lubricants

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	1.5	0	7	13	20	27	100
MOBILE4	1.5	0	7	13	20	27	27

Accessories (None)

Table 8 (cont'd)

Class IIB-IV--Light Heavy-Duty Vehicles (cont'd)
Future Non-Engine Related Fuel Economy Improvements

Automatic Overdrive

Source	% FE Imprv.	% Penetration (cumulative) 1982	1983	1984	1985	1986	2000
MOBILE3[1]	5.0	0	3	6	10	13	48
MOBILE4	5.0	0	3	6	10	13	13

Manual Overdrive

Source	% FE Imprv.	% Penetration (cumulative) 1982	1983	1984	1985	1986	2000
MOBILE3[1]	5.0	10	12	14	16	18	40
MOBILE4	5.0	10	12	14	16	18	18

Electronic Transmission Control

Source	% FE Imprv.	% Penetration (cumulative) 1982	1983	1984	1985	1986	2000
MOBILE3[1]	0.0	0	0	0	0	0	0
MOBILE4		0	0	0	0	0	0

Table 9

Class VI-VIIIa--Medium Heavy-Duty Vehicles
Future Non-Engine Related Fuel Economy Improvements

Weight Reduction (none)

Radials

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	3.2	14	14	14	14	14	0
MOBILE4	3.2	14	14	14	14	14	14

Advanced Radials

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	6.0	0	1	2	3	4	30
MOBILE4	6.0	0	1	2	3	4	4

Aerodynamics (body) - none

Aerodynamics (add-on)

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	2.5	5	5	6	6	7	20
MOBILE4	2.5	5	5	6	6	7	7

Drivetrain Lubricants

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	1.5	0	7	13	20	27	100
MOBILE4	1.5	0	7	13	20	27	27

Fan Drives

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	5.3	50	60	70	80	90	100
MOBILE4	5.3	50	60	70	80	90	90

Speed Control

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	6.0	0	1	2	3	4	15
MOBILE4	6.0	0	1	2	3	4	4

Table 10

Class VIIIb--Heavy Heavy-Duty Vehicles
Future Non-Engine Related Fuel Economy Improvements

Weight Reduction (none)

Radials

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	6.8	65	62	58	54	50	0
MOBILE4	6.8	65	62	58	54	50	50

Advanced Radials

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	10.2	1.7	5	10	15	20	70
MOBILE4	10.2	1.7	5	10	15	20	20

Aerodynamics (body) - none

Aerodynamics (add-on)

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	2.5	22	24	27	29	32	58
MOBILE4	2.5	22	24	27	29	32	32

Drivetrain Lubricants

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	1.5	0	7	13	20	27	100
MOBILE4	1.5	0	7	13	20	27	27

Fan Drives

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	6.8	98	98	99	99	100	100
MOBILE4	6.8	98	98	99	99	100	100

Speed Control

		% Penetration (cumulative)					
Source	% FE Imprv.	1982	1983	1984	1985	1986	2000
MOBILE3[1]	5.0	8	10	11	13	14	50
MOBILE4	5.0	8	10	11	13	14	14

TABLE 11

ANNUAL FUEL ECONOMY IMPROVEMENTS (RELATIVE TO 1982)

YEAR	CLASS 2B	CLASS 3	CLASS 4	CLASS 5	CLASS 6	CLASS 7	CLASS 8A	CLASS 8B	TRANSIT	COMMERCIAL	SCHOOL
DIESEL											
83	1.00092	1	1	1	1.00823	1.00770	1.00975	1.00085	1	1	1
84	1.00182	1	1	1	1.01838	1.01541	1.01788	1.00354	1	1	1
85	1.00279	1	1	1	1.02669	1.02318	1.02615	1.00462	1	1	1
86	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
87	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
88	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
89	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
90	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
91	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
92	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
93	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
94	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
95	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
96	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
97	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
98	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
99	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
2000	1.00456	1	1	1	1.03338	1.03091	1.03428	1.00735	1	1	1
GASOLINE											
83	1.00087	1.00086	1.00087	1.00112	1.00838	1.00681	1.00695	1	1	1	1
84	1.00171	1.00170	1.00172	1.00319	1.01598	1.01294	1.01400	1	1	1	1
85	1.00367	1.00339	1.00308	1.00614	1.02353	1.02041	1.02115	1	1	1	1
86	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
87	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
88	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
89	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
90	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
91	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
92	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
93	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
94	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
95	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
96	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
97	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
98	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
99	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1
2000	1.00684	1.00643	1.00547	1.00986	1.03073	1.02774	1.02875	1	1	1	1

Table 12

1982 TIUS Vehicle Stock and VMT
By Class, Range, and Fuel Type

		Diesel		Gasoline	
Vehicle Class	Range	Stock	Avg VMT	Stock	Avg VMT
Class 2	Local	19573	13077	8802070	10834
	Short	3383	30387	1362678	13805
	Long	2126	29853	412753	13178
Class 3	Local	7817	15482	45922	5596
	Short	1781	36298	7393	13439
	Long	379	53414	543	6472
Class 4	Local	3000	16558	147078	7090
	Short	569	28662	25239	13669
	Long	0	NA	5536	8101
Class 5	Local	3914	16752	256128	6420
	Short	1458	34487	28325	13256
	Long	307	30582	3356	12803
Class 6	Local	41270	17489	718706	8214
	Short	20527	28009	95819	15151
	Long	3826	46970	14052	15565
Class 7	Local	113119	19643	103120	10746
	Short	41889	34705	18553	18763
	Long	11493	52420	2599	23129
Class 8A	Local	142493	19163	67339	8599
	Short	58534	41006	7504	16934
	Long	44179	79133	1700	11093
Class 8B	Local	247518	30802	6662	12953
	Short	231957	56621	1610	25380
	Long	253282	87750	521	95892

fuel economy improvements for gasoline and diesel vehicles arises from the different weighting of the individual fuel economy improvements due to different long-range, short-range, and local distributions of gasoline and diesel vehicles.

If the percent of the fleet affected was less than the percent of vehicles used for long-range transport, then only long-range vehicles were credited with fuel economy improvements. The percent of fleet affected had to be greater than both the combined long-range and short-range vehicle use fractions in order to credit any fuel economy improvement to the urban (local) vehicles. The overall effect of a given technology is dependent on the degree that the technology is applied throughout the class and on the breakdown of the class between the various use categories. The computer program used to perform these calculations is shown in Appendix C.

After all of the future non-engine-related fuel economy improvements are calculated for each class and time period, they are applied to the most recent historic class-specific (1982) conversion factor to yield future class-specific conversion factors. Some of the fuel economy improvements discussed had already penetrated a portion of the fleet by 1982, and their increasing benefits were realized as a larger percent of the fleet incorporated those improvements in later model years. This 1982 baseline penetration was subtracted from the penetration of each future year to obtain the net percent improvement from 1982 to the year in question. These future class-specific conversion factors are shown along with the historic values in Tables 5 and 6. For reference, the MOBILE3 values are shown in Table A-2. As can be seen, the differences in future class specific conversion factors between the MOBILE3 and MOBILE4 analyses are typically fairly small.

IV. Fleet-Average Conversion Factors

Fleet-average conversion factors were calculated by VMT weighting the class-specific conversion factors. The VMT weighting factor for each class was determined by normalizing the product of: 1) the HDV sales fraction, 2) the diesel or gasoline sales fraction, 3) the annual VMT per vehicle, and 4) the urban travel fraction. The resulting diesel and gasoline VMT-weighting factors are listed in Tables 13 and 14. The individual factors that make up the VMT weighting factor are discussed in the paragraphs below.

A. Sales Fractions

Historical class-specific truck sales figures for the 1962 to 1971 timeframe were calculated from the sales fractions used in the MOBILE3 conversion factors analysis and an estimate of the entire fleetwide truck sales from the MVMA fact book.[12] For the 1972 to 1986 timeframe, the MVMA fact sheets were

TABLE 13

DIESEL VMT WEIGHTING FACTORS

YEAR	CLASS 2B	CLASS 3	CLASS 4	CLASS 5	CLASS 6	CLASS 7	CLASS 8A	CLASS 8B	TRANSIT	COMMERCIAL	SCHOOL
62	0	0.001857	0.006265	0.029096	0.059262	0.288106	0.056916	0.433105	0.102715	0.022674	0
63	0.000298	0.001955	0.006603	0.030574	0.074583	0.250074	0.058430	0.470605	0.087329	0.019544	0
64	0.000281	0.001983	0.006572	0.028644	0.078960	0.215354	0.058719	0.504553	0.086106	0.018825	0
65	0.000534	0.001960	0.006448	0.025693	0.076819	0.188052	0.059259	0.538508	0.084195	0.018528	0
66	0.000956	0.001866	0.006187	0.023233	0.079105	0.166828	0.054712	0.564296	0.084051	0.018760	0
67	0.000583	0.001695	0.005770	0.020407	0.080735	0.148593	0.050608	0.593169	0.081145	0.017292	0
68	0.000302	0.001048	0.003499	0.014995	0.072603	0.135289	0.048928	0.641956	0.066947	0.014427	0
69	0	0.000492	0.001600	0.007377	0.064548	0.121463	0.046530	0.680810	0.063071	0.014105	0
70	0	0.000097	0.000335	0.001551	0.058239	0.110512	0.044494	0.727843	0.046619	0.010304	0
71	0	0.000376	0.000350	0.001196	0.043095	0.109401	0.044928	0.716442	0.068596	0.015611	0
72	0	0.001082	0.000209	0.000688	0.026896	0.090385	0.049568	0.749545	0.067097	0.014524	0
73	0	0.001109	0.000196	0.000732	0.028316	0.087184	0.053043	0.752974	0.062592	0.013850	0
74	0	0.000178	0.000177	0.000433	0.032625	0.072546	0.053362	0.730991	0.089289	0.020393	0
75	0	0.000880	0.000316	0.000525	0.041553	0.108279	0.053745	0.581230	0.173583	0.039884	0
76	0	0.000890	0.000002	0.000170	0.054580	0.085276	0.062639	0.649996	0.119146	0.027297	0
77	0.001142	0	0	0	0.052112	0.100055	0.067025	0.723383	0.045608	0.010626	0.000045
78	0	0	0	0	0.045888	0.117802	0.061700	0.697124	0.061664	0.015381	0.000438
79	0.038501	0	0	0	0.049611	0.116016	0.053913	0.675116	0.052130	0.012963	0.001747
80	0.118076	0	0	0	0.035671	0.174960	0.041751	0.518107	0.087514	0.018687	0.005229
81	0.166079	0	0	0	0.043903	0.143025	0.039112	0.503144	0.080496	0.016865	0.007371
82	0.279754	0	0	0	0.025049	0.185028	0.029118	0.390423	0.064281	0.014142	0.012201
83	0.340036	0	0	0	0.023077	0.149811	0.060202	0.329455	0.071731	0.015285	0.010398
84	0.278909	0	0	0	0.025132	0.149432	0.063873	0.422003	0.042274	0.009160	0.009212
85	0.359162	0	0	0	0.025226	0.156651	0.060630	0.337899	0.037123	0.008378	0.014928
86	0.345845	0	0	0	0.016942	0.166952	0.083013	0.306912	0.047108	0.010202	0.023022
87	0.360157	0	0	0	0.026149	0.176706	0.051024	0.310679	0.043951	0.009665	0.021665
88	0.373600	0	0	0	0.026481	0.179669	0.049775	0.294812	0.043514	0.009569	0.022576
89	0.386721	0	0	0	0.026723	0.182468	0.049151	0.280237	0.042241	0.009245	0.023211
90	0.399826	0	0	0	0.026816	0.184817	0.048092	0.266575	0.040978	0.009160	0.023734
91	0.406272	0	0	0	0.027334	0.185261	0.047459	0.260521	0.040270	0.009001	0.023879
92	0.413538	0	0	0	0.027707	0.184945	0.046719	0.254793	0.039642	0.008634	0.024020
93	0.411888	0	0	0	0.028121	0.187778	0.046790	0.252939	0.039538	0.008611	0.024331
94	0.410507	0	0	0	0.028482	0.189331	0.046877	0.253071	0.038608	0.008591	0.024528
95	0.408283	0	0	0	0.028687	0.188937	0.046888	0.255623	0.038458	0.008558	0.024562
96	0.408190	0	0	0	0.028563	0.188955	0.047005	0.256155	0.038396	0.008319	0.024411
97	0.409439	0	0	0	0.028844	0.187976	0.046862	0.256428	0.037602	0.008328	0.024516
98	0.410069	0	0	0	0.029189	0.187136	0.046684	0.256509	0.037614	0.008331	0.024464
99	0.411282	0	0	0	0.029544	0.185162	0.046522	0.257152	0.037639	0.008336	0.024359
2000	0.412563	0	0	0	0.030087	0.183749	0.046196	0.257247	0.037687	0.008347	0.024120

TABLE 14

GASOLINE VMT WEIGHTING FACTORS

YEAR	CLASS 2B	CLASS 3	CLASS 4	CLASS 5	CLASS 6	CLASS 7	CLASS 8A	CLASS 8B	TRANSIT	COMMERCIAL	SCHOOL
62	0.084704	0.019007	0.057896	0.296950	0.258296	0.089215	0.008790	0.110036	0.026182	0.005779	0.043140
63	0.094014	0.018488	0.056286	0.288189	0.250137	0.086321	0.009960	0.117392	0.021901	0.004901	0.052407
64	0.105457	0.018080	0.054385	0.282254	0.246712	0.086043	0.011445	0.122425	0.021059	0.004604	0.047530
65	0.116464	0.017485	0.052400	0.274245	0.244112	0.085580	0.012909	0.122826	0.019333	0.004254	0.050386
66	0.138557	0.015221	0.046251	0.241192	0.265965	0.091582	0.015694	0.113609	0.017085	0.003813	0.051025
67	0.135989	0.013409	0.041699	0.213045	0.293627	0.099727	0.018955	0.106574	0.014703	0.003133	0.059133
68	0.154827	0.013048	0.039422	0.201771	0.301649	0.106938	0.022077	0.089531	0.009465	0.002040	0.059226
69	0.175493	0.012866	0.037710	0.192051	0.312592	0.116054	0.025928	0.068340	0.006480	0.001449	0.051031
70	0.195991	0.011357	0.035418	0.180033	0.321358	0.124531	0.029962	0.041503	0.002770	0.000612	0.056460
71	0.196513	0.043598	0.036727	0.138186	0.338954	0.117825	0.028507	0.041946	0.004172	0.000949	0.052617
72	0.192881	0.122343	0.021419	0.077660	0.373808	0.091790	0.029358	0.042843	0.003984	0.000862	0.043046
73	0.224874	0.101750	0.016300	0.067018	0.387429	0.081510	0.027387	0.047901	0.004143	0.000916	0.040765
74	0.234297	0.019508	0.017550	0.047243	0.472006	0.069016	0.026355	0.056166	0.007129	0.001628	0.049096
75	0.357016	0.051386	0.016731	0.030592	0.370605	0.058600	0.013915	0.029876	0.010033	0.002305	0.058935
76	0.409473	0.107640	0.000220	0.020512	0.331035	0.041806	0.011488	0.019029	0.007993	0.001831	0.048968
77	0.649578	0.046816	0.005082	0.007271	0.220045	0.030924	0.007820	0	0.001818	0.000423	0.030218
78	0.651758	0.051236	0.009031	0.005816	0.206740	0.035991	0.007277	0	0.002719	0.000678	0.028749
79	0.683093	0.029579	0.003989	0.005145	0.193553	0.045587	0.007229	0	0.001724	0.000428	0.029667
80	0.794112	0.009218	0.000042	0.003479	0.091797	0.062725	0.004381	0	0.001525	0.000325	0.032390
81	0.805366	0.000556	0.000033	0.004084	0.100729	0.060668	0.003948	0	0	0	0.024612
82	0.862236	0	0.000021	0.002756	0.040117	0.070993	0.002088	0	0	0	0.021786
83	0.894882	0	0	0.001928	0.034206	0.051175	0.001388	0	0	0	0.016418
84	0.867980	0	0	0.008223	0.031890	0.071845	0.001904	0	0	0	0.018156
85	0.880005	0.024472	0	0.006260	0.019374	0.059063	0.001120	0	0	0	0.009702
86	0.886304	0	0	0.009106	0.018660	0.073662	0.001229	0	0	0	0.011035
87	0.881406	0	0	0.009063	0.023061	0.077695	0.000456	0	0	0	0.008316
88	0.884543	0	0	0.009021	0.021805	0.077691	0.000246	0	0	0	0.006690
89	0.886511	0	0	0.008983	0.020853	0.078123	0	0	0	0	0.005528
90	0.888117	0	0	0.008950	0.019858	0.078533	0	0	0	0	0.004540
91	0.888427	0	0	0.008962	0.019595	0.079254	0	0	0	0	0.003759
92	0.889070	0	0	0.008967	0.019350	0.079614	0	0	0	0	0.002995
93	0.890468	0	0	0.008994	0.018765	0.079414	0	0	0	0	0.002357
94	0.891933	0	0	0.008895	0.018288	0.079098	0	0	0	0	0.001784
95	0.893674	0	0	0.008926	0.017940	0.078179	0	0	0	0	0.001279
96	0.895312	0	0	0.008806	0.017559	0.077417	0	0	0	0	0.000904
97	0.896593	0	0	0.008801	0.017593	0.076467	0	0	0	0	0.000544
98	0.897280	0	0	0.008673	0.017789	0.076067	0	0	0	0	0.000189
99	0.898241	0	0	0.008662	0.017972	0.075123	0	0	0	0	0
2000	0.898844	0	0	0.008529	0.018257	0.074368	0	0	0	0	0

relied on for the class-specific sales of all trucks sold domestically in the U.S., with the exception of Class 2B, Class 8A, and Class 8B.[4] For Classes 8A and 8B, the MVMA fact sheets were relied on for the total Class 8 sales, but this was broken up into Class 8A and 8B by using the sales information in the EEA conversion factors report, and the Department of Energy's 13th Periodical Report[13,14] (for the years where data was available) to determine the ratio of Class 8B to Class 8 Sales. Class 2B sales were taken from the 13th Periodical Report, as that was the most recent source for strictly Class 2B new vehicle registrations. (Class 2B new vehicle registrations were assumed to be representative of Class 2B domestic sales.)

Historical transit bus sales were taken from the APTA Transit Fact Book.[7] Commercial bus sales were assumed to be 82 percent of transit bus sales based on fleet registrations. School bus sales were taken from the MVMA fact sheets in similar fashion as the truck sales. Since the 1962 to 1971 values for school buses were not included in the MOBILE3 work, and were not available in our MVMA fact sheets, they were estimated based on the size of the school bus fleet given in the FHA Highway Statistics.[6]

Future class sales were determined by taking the historical sales and projecting them forward in a manner similar to that used in the MOBILE3 analysis. Class 2B was projected using the 13th Periodical Report.[14] Classes 3 and 4 sales had gone to zero by 1982. As no information was found to suggest otherwise, the sales for these classes was assumed to remain zero. Class 5 sales had been projected to go to zero in the MOBILE3 analysis. However, recent history has shown this not to be true. As a result of no available precedent for projecting Class 5 sales, the additive two percent increase per year in sales which had been assumed for Class 6 in the EEA conversion factor analysis was assumed for this analysis to be representative of Class 5 as well.[13] The future sales projections which were used in the MOBILE3 analysis for Classes 6 and 7 were used here as well, with the exception that new starting points were selected based on the sales information available for recent years. Class 8A was projected using a historically based fraction of 9.38 percent of the total of Classes 7 and 8, while Class 8B was projected using the 13th periodical report,[14] with the exception that the values were modified downward to account for differences seen in the historical data between registrations from the 13th Periodical Report and MVMA sales. Transit and commercial bus sales were projected assuming an additive two percent increase every year. School bus sales were projected using an extrapolation of the historical data.

Once all of these model year specific class-specific sales were estimated, the corresponding sales fractions could be determined. Historical fractions no longer match those presented in the MOBILE3 conversion factors report and shown in Table A-1 due to the addition of the two classes of school buses and commercial buses. The resulting sales and sales fractions are listed in Tables 15 and 16, respectively. Comparison of these sales fractions with the estimates made by MOBILE3 and shown in Table A-3 demonstrate the trend toward the lighter truck classes seen in recent years.

B. Diesel Fractions and Gasoline Fractions

The 1962 to 1982 diesel sales fractions used to calculate the VMT-weighting factors are identical to those used in the MOBILE3 conversion factor analysis, and were based on factory sales by U.S. domestic manufacturers and exports from Canada to the U.S. The gasoline fractions are simply 1.0 minus the diesel fraction. For the 1983 to 1986 time frame, the MVMA fact sheets used for determining the total class sales were used with the exception that once again estimates for Class 2B relied on the 13th Periodical Report.[4,14]

Future diesel penetration rates into the individual classes were projected from the sales information as described above. With the exception of Class 6, all of the truck classes were assumed to have the same diesel penetrations in the year 1997 as in the MOBILE3 analysis. This assumption was not practical for Class 6 due to the much higher dieselization of this class in recent years than had been assumed in the MOBILE3 analysis. Instead, since the sales data as seen in Table 15 showed that Class 7 vehicles may be replacing Class 6 vehicles, the 1997 penetration for Class 7 was also assumed for Class 6. Transit and commercial buses were assumed to remain all diesel, as they have already been completely diesel for a number of years, and this is not expected to change. Neither EEA nor the MOBILE3 conversion factor analysis had projected school bus sales. Historical MVMA sales data showed that in the span of just 10 years since diesel engines entered the school bus market, they have already reached nearly 70 percent penetration. As a result, by extrapolating this historical data, school bus sales were projected to become 100 percent diesel by 1999. Both historical and future diesel penetrations for trucks and buses are shown in Table 17. Once again, the MOBILE3 diesel penetrations are shown in Tables A-1 and A-3. A comparison of the two shows little difference in all but Class 6 trucks, where a greater future diesel penetration is now projected.

Table 15
Total Annual Sales
(In Thousands)

Year	Class2B	Class3	Class4	Class5	Class6	Class7	Class8A	Class8B	Transit	Commercial	School
62	21	7.3	22.2	118.6	83.6	33.7	5.1	38.5	2.6	2.1	24.0
63	25	7.6	23.2	123.4	89.3	36.0	6.5	49.0	2.6	2.1	31.0
64	26	7.0	20.9	112.4	83.7	33.7	7.1	53.6	2.6	2.1	26.0
65	31	7.4	22.3	119.2	91.8	36.9	8.9	67.6	3.0	2.5	30.0
66	39	6.8	20.5	110.7	104.9	38.3	9.7	73.2	3.1	2.5	32.0
67	32	5.1	15.5	81.8	96.3	32.3	8.5	64.3	2.5	2.0	31.0
68	39	5.1	15.4	81.9	104.5	35.7	10.0	75.3	2.2	1.8	33.0
69	45	5.0	14.8	78.0	110.0	38.2	11.3	85.0	2.2	1.8	29.0
70	42	3.7	11.4	60.4	94.7	33.5	10.4	78.4	1.4	1.2	27.0
71	49	16.3	13.6	53.5	111.1	37.1	11.8	88.9	2.4	2.0	29.0
72	61	57.8	10.1	38.0	149.1	37.1	15.7	114.6	2.9	2.4	30.0
73	77	52.6	8.4	35.8	169.3	38.6	18.1	136.5	3.2	2.6	31.0
74	71	8.9	8.0	22.3	183.5	31.1	17.7	139.5	4.8	4.1	33.0
75	90	19.5	6.3	12.0	120.4	23.8	9.1	61.6	5.3	4.5	32.9
76	110	43.4	0.1	8.6	120.5	21.7	12.3	87.2	4.7	4.0	29.1
77	280	30.1	3.2	4.8	132.2	31.5	17.3	130.0	2.4	2.1	28.9
78	290	34.0	6.0	4.0	128.8	41.0	18.0	143.0	3.8	3.5	28.7
79	280	17.4	2.4	3.1	113.4	45.1	17.2	153.5	3.4	3.2	27.3
80	302	4.8	0.0	1.9	51.2	54.4	10.4	93.5	4.6	3.6	28.5
81	274	0.2	0.0	1.9	51.4	44.2	9.4	89.6	4.1	3.2	21.0
82	321	0.0	0.0	1.3	23.1	53.2	6.35	64.2	3.0	2.5	22.3
83	419	0.0	0.0	1.1	24.8	50.8	15.2	66.1	4.1	3.2	21.4
84	464	0.0	0.0	5.5	30.7	75.6	23.4	123.0	3.4	2.8	26.9
85	588	19.4	0.0	5.1	27.4	82.2	23.6	105.7	3.3	2.7	27.8
86	465	0.0	0.0	5.7	18.2	78.0	28.4	84.7	3.6	3.0	32.3
87	484	0.0	0.0	5.9	26.5	87.5	18.6	92.3	3.7	3.0	30.3
88	504	0.0	0.0	6.0	27.0	92.0	19.0	91.4	3.8	3.1	31.0
89	523	0.0	0.0	6.1	27.5	96.5	19.4	90.5	3.9	3.2	31.7
90	543	0.0	0.0	6.2	28.0	101.0	19.7	89.7	3.9	3.2	32.5
91	556	0.0	0.0	6.3	29.0	105.0	20.3	91.4	4.0	3.3	33.2
92	570	0.0	0.0	6.4	30.0	108.5	20.9	93.2	4.1	3.3	33.9
93	583	0.0	0.0	6.5	30.8	112.5	21.5	95.0	4.2	3.4	34.5
94	597	0.0	0.0	6.6	31.5	116.0	22.1	97.7	4.2	3.5	35.1
95	610	0.0	0.0	6.7	32.3	118.5	22.8	101.3	4.3	3.5	35.6
96	630	0.0	0.0	6.9	33.0	122.0	23.5	104.9	4.4	3.6	36.1
97	647	0.0	0.0	7.0	34.0	124.0	24.0	107.6	4.5	3.7	36.7
98	664	0.0	0.0	7.1	35.3	126.5	24.5	110.3	4.6	3.7	37.1
99	681	0.0	0.0	7.23	36.5	128.0	24.9	113.0	4.7	3.8	37.6
2000	699	0.0	0.0	7.4	38.0	130.0	25.4	115.6	4.7	3.9	38.0

Table 16

TRUCK SALES FRACTIONS

Year	Class2B	Class3	Class4	Class5	Class6	Class7	Class8A	Class8B	Transit	Commercial	School
62	.059	.020	.062	.330	.233	.094	.014	.107	.007	.006	.067
63	.063	.019	.059	.312	.226	.091	.016	.124	.007	.006	.078
64	.069	.019	.056	.300	.223	.090	.019	.143	.007	.006	.069
65	.074	.018	.053	.283	.218	.088	.021	.161	.007	.006	.071
66	.089	.016	.047	.251	.238	.087	.022	.166	.007	.006	.073
67	.087	.014	.042	.220	.259	.087	.023	.173	.007	.005	.084
68	.096	.013	.038	.203	.259	.088	.025	.186	.006	.004	.082
69	.107	.012	.035	.186	.262	.091	.027	.202	.005	.004	.069
70	.116	.010	.031	.666	.260	.092	.029	.215	.004	.003	.074
71	.118	.039	.033	.129	.268	.090	.028	.214	.006	.005	.071
72	.117	.112	.019	.073	.288	.072	.030	.221	.006	.005	.058
73	.134	.092	.015	.063	.295	.067	.032	.238	.006	.005	.054
74	.136	.017	.015	.043	.350	.059	.034	.266	.009	.008	.063
75	.233	.015	.016	.031	.312	.062	.024	.160	.014	.012	.085
76	.249	.098	.000	.019	.273	.049	.028	.197	.011	.009	.066
77	.423	.045	.005	.007	.199	.048	.026	.196	.004	.003	.044
78	.414	.049	.009	.006	.184	.059	.026	.204	.005	.005	.041
79	.420	.026	.004	.005	.170	.068	.026	.230	.005	.005	.041
80	.544	.009	.000	.003	.092	.098	.019	.169	.008	.007	.051
81	.549	.000	.000	.004	.103	.089	.019	.180	.008	.006	.042
82	.646	No Sales	.000	.003	.046	.107	.013	.129	.006	.005	.045
83	.692	.000	.000	.002	.041	.084	.025	.109	.007	.005	.035
84	.614	.000	.000	.007	.041	.100	.031	.163	.005	.004	.036
85	.664	.022	No Sales	.006	.031	.093	.027	.119	.004	.003	.031
86	.647	No. Sales	No Sales	.008	.025	.109	.039	.118	.005	.004	.045
87	.644	No. Sales	No Sales	.008	.035	.116	.025	.123	.005	.004	.040
88	.648	No. Sales	No Sales	.008	.035	.118	.024	.118	.005	.004	.040
89	.652	No. Sales	No Sales	.008	.034	.120	.024	.113	.005	.004	.040
90	.656	No. Sales	No Sales	.007	.034	.122	.024	.108	.005	.004	.039
91	.655	No. Sales	No Sales	.007	.034	.124	.024	.108	.005	.004	.039
92	.655	No. Sales	No Sales	.007	.034	.125	.024	.107	.005	.004	.039
93	.654	No. Sales	No Sales	.007	.034	.126	.024	.107	.005	.004	.039
94	.653	No. Sales	No Sales	.007	.034	.127	.024	.107	.005	.004	.038
95	.652	No. Sales	No Sales	.007	.034	.127	.024	.108	.005	.004	.038
96	.653	No. Sales	No Sales	.007	.034	.127	.024	.109	.005	.004	.037
97	.655	No. Sales	No Sales	.007	.034	.125	.024	.109	.005	.004	.037
98	.655	No. Sales	No Sales	.007	.035	.125	.024	.109	.005	.004	.037
99	.657	No. Sales	No Sales	.007	.035	.123	.024	.109	.004	.004	.036
2000	.658	No. Sales	No Sales	.007	.036	.122	.024	.109	.004	.004	.036

Table 17

Diesel Sales Fractions

Year	Class2B	Class3-5	Class6	Class7	Class8A	Class8B	Transit	Commercial	School
62	0	.014	.042	.421	.600	.547	.547	.547	0.0
63	.001	.018	.063	.436	.616	.595	.595	.595	0.0
64	.001	.022	.084	.442	.624	.642	.642	.642	0.0
65	.002	.026	.105	.447	.632	.690	.690	.690	0.0
66	.003	.029	.100	.413	.583	.721	.721	.721	0.0
67	.002	.031	.094	.379	.535	.751	.751	.751	0.0
68	.001	.022	.088	.364	.514	.809	.809	.809	0.0
69	0	.012	.082	.348	.492	.867	.867	.867	0.0
70	0	.003	.076	.333	.470	.925	.925	.925	0.0
71	0	.003	.054	.341	.482	.923	.923	.923	0.0
72	0	.003	.031	.348	.492	.923	.923	.923	0.0
73	0	.004	.034	.382	.540	.921	.921	.921	0.0
74	0	.004	.038	.415	.586	.920	.920	.920	0.0
75	0	.005	.041	.449	.634	.920	.914	.914	0.0
76	0	.003	.071	.514	.726	.960	.919	.919	0.0
77	.001	0	.100	.578	.770	1.0	.943	.943	.001
78	0	0	.106	.615	.794	1.0	.943	.943	.011
79	.041	0	.174	.606	.818	1.0	.965	.965	.051
80	.081	0	.242	.598	.841	1.0	.979	.979	.116
81	.122	0	.309	.589	.865	1.0	1.0	1.0	.291
82	.162	0	.377	.580	.889	1.0	1.0	1.0	.316
83	.184	0	.399	.617	.962	1.0	1.0	1.0	.342
84	.198	0	.493	.589	.962	1.0	1.0	1.0	.350
85	.216	0	.579	.627	.973	1.0	1.0	1.0	.589
86	.232	0	.527	.617	.981	1.0	1.0	1.0	.690
87	.250	0	.590	.635	.989	1.0	1.0	1.0	.745
88	.260	0	.610	.646	.994	1.0	1.0	1.0	.794
89	.270	0	.626	.655	1.0	1.0	1.0	1.0	.830
90	.280	0	.642	.662	1.0	1.0	1.0	1.0	.861
91	.290	0	.656	.670	1.0	1.0	1.0	1.0	.886
92	.300	0	.668	.677	1.0	1.0	1.0	1.0	.910
93	.300	0	.679	.684	1.0	1.0	1.0	1.0	.929
94	.300	0	.688	.689	1.0	1.0	1.0	1.0	.946
95	.300	0	.695	.694	1.0	1.0	1.0	1.0	.961
96	.300	0	.699	.698	1.0	1.0	1.0	1.0	.972
97	.300	0	.700	.700	1.0	1.0	1.0	1.0	.983
98	.300	0	.700	.700	1.0	1.0	1.0	1.0	.994
99	.300	0	.700	.700	1.0	1.0	1.0	1.0	1.0
2000	.300	0	.700	.700	1.0	1.0	1.0	1.0	1.0

C. Annual Vehicle Miles Travelled

EEA's analysis of the 1982 TIUS provided class-specific, fuel-specific annual VMTs per vehicle for long-range, short-range, and local applications individually as seen in Table 12.[5] These values represent the 1982 calendar year VMT per vehicle of the vehicles surveyed in the analysis. Since it is known that diesel penetration affects the average annual VMT per vehicle, the EEA calendar-year values were converted to model year specific VMT per vehicle values using the model year specific diesel penetrations developed in the previous section. An example of this conversion (for Class 2B for the 1986 model year) follows.

To begin this calculation, the Class 2B vehicle stock and VMT per vehicle values were taken from the 1982 TIUS.

Vehicle Range	TIUS Diesel Stock	TIUS Gas Stock	TIUS Total Stock	TIUS Diesel Distribution	TIUS Diesel/Gas VMT/Vehicle
Local	19573	8802070	8821643	0.7804	13077/10834
Short	3383	1362678	1366061	0.1349	30387/13805
Long	2126	412753	414879	0.0847	29853/13178
Total	25082	10577501	10602583	1.0000	-

The diesel sales fraction for 1986 Class 2B trucks was then taken from Table 16 and multiplied by the total TIUS stock to determine the number of vehicles (out of a fleet the size of the TIUS fleet) that should be diesel for the 1986 model year. To determine the breakdown of these vehicles among the local, short-range, and long-range categories, it was then assumed that gasoline vehicles switch over to diesel among these categories in the ratio in which diesel vehicles already existed in those categories until the long-range application became completely diesel. At that time, those that would have been added to the long-range category were added to the short-range category until it was completely diesel. Any additional diesel vehicles beyond this were all added into the local category. From this, the number of additional diesels (or fewer gasoline trucks) over and above that determined in the TIUS can be calculated, as well as the remaining gasoline trucks.

	1986 Total Diesel Stock	Additional Diesel Stock	Net Gasoline Stock
Local		1900053	6902017
Short		328443	1034235
Long		206221	206532
Total	2459799	2434717	8142784

At this point, these fuel specific and range specific vehicle stocks were multiplied by the corresponding annual VMTs (also shown in Table 12). Diesel vehicles which had been gasoline were assumed to have the annual VMT of the gasoline vehicles which they replaced, so that switching fuels did not increase the total VMT of the vehicle class.

	1986 Diesel Fleet VMT (Billions)	1986 Gasoline Fleet VMT (Billions)
Local	20.841	74.776
Short	4.637	14.278
Long	2.781	2.722
Total	28.259	91.776

At this point, by merely dividing the total VMT for all vehicle ranges by the corresponding model year specific vehicle stocks, estimates of the Class 2B 1986 model year diesel and gasoline average annual VMTs could be determined.

	1986 Diesel Avg Annual VMT/Veh	1986 Gasoline Avg Annual VMT/Veh
Local	10857	10834
Short	13974	13805
Long	13348	13178
Avg	11488	11271

As a result of this analysis, the average annual VMT for an entire class (gas and diesel) remains constant while they change for both gasoline and diesel vehicles individually. This is reasonable, since a trend to more diesel vehicles should not cause a greater number of miles to be driven by an entire fleet. A similar analysis was then performed for all vehicle classes for all model years of concern.

The TIUS information did not include buses, so an equivalent annual VMT per bus had to be determined. The value for transit buses was obtained from data in the APTA transit fact book,[7] while the values for the commercial and school buses were obtained from the FHA Highway Statistics.[6] These values, however, may not be entirely appropriate for inclusion into a data base that consists mostly of trucks, since the life expectancy of a bus is typically longer than that of a truck. Lifetime VMT per vehicle is actually a more appropriate measure of a vehicle's contribution to a model year's lifetime emissions. This is true because the conversion factors are determined by model year and apply throughout the entire life of that model year's vehicles. When vehicles' lives are the same in terms of years, the two approaches (annual and lifetime VMT) yield the same results. But since the lives of buses (in

years) are longer than other heavy-duty vehicles, the annual approach would underestimate their contribution to their model year's fleet-wide lifetime emissions. Thus, an equivalent annual bus VMT was estimated by multiplying the average annual Class 8B VMT per vehicle of 57,136 miles by the ratio of lifetime bus VMT to lifetime Class 8B VMT. Due to a lack of any other means of estimating the lifetime VMT of the buses, an estimate was determined by dividing the annual fleet VMTs by the corresponding new bus sales over a range of 9 to 19 years for the different bus classes. This was done for all three bus classes as shown in Tables 18 through 20. The resulting annual VMT per vehicle values for both trucks and buses for all model years can be seen in Tables 21 and 22. The annual VMT per vehicle estimates made for MOBILE3 are shown in Tables A-1 and A-3. Overall the new estimates are probably not that much different from MOBILE3's, but individual classes may vary significantly.

D. Urban Travel Fractions

The MOBILE3 conversion factor analysis utilized TIUS data similar to that used above for the annual VMT per vehicle calculations to determine class-specific, fuel-specific, model year specific urban travel fractions. The model year specific, range-specific fleet VMTs calculated in the example above were reweighted based on the assumption that only 85 percent of a vehicle's VMT is in its primary use category; the remaining 15 percent being split equally between the other two categories. The fraction of VMT which was local was then assumed to be the urban travel fraction.

Although this method is still possible using the data from the 1982 TIUS, more accurate information has since become available. The University of Michigan Transportation Research Institute (UMTRI) performed a survey supplemental to the 1982 TIUS in which they contacted 8000 truck owners and traced four days of operation on maps to determine actual truck usage patterns. The fraction of vehicle miles for each class within the boundaries of urban areas with populations of 50,000 or more was assumed to be the urban travel fraction for that class. They did not survey class 2B trucks. As a result, the values for Class 3-5 straight trucks will be used as a surrogate for Class 2B. They also did not survey buses. Therefore, transit buses were assumed to be entirely urban. Commercial and school bus urban travel fractions were taken from an average of FHA data.[6]

The urban travel fractions obtained from the UMTRI data are likely to be much more accurate for those vehicle classes surveyed than the values obtained from the TIUS, since no assumptions as to the percent of travel in a vehicle's primary use category, or as to what constituted urban travel had to be made. Unfortunately, this method provided only 1985 calendar

Table 18

Transit Bus Annual VMT per Vehicle

Year	Fleet VMT (Millions)	New Sales	VMT/Sales
1967	1526.0	2500	610400
1968	1508.2	2228	676930
1969	1478.3	2230	662915
1970	1409.3	1424	989677
1971	1375.5	2514	547136
1972	1308.0	2904	450413
1973	1370.4	3200	428250
1974	1431.0	4818	297011
1975	1526.0	5261	290059
1976	1581.4	4745	333277
1977	1623.3	2437	666106
1978	1630.5	3805	428515
1979	1633.6	3440	474884
1980	1677.2	4572	366842
1981	1684.6	4059	415028
1982	1668.8	2962	563403
1983	1677.8	4081	411125
1984	1621.9	3444	470935
1985	1771.3	3296	537409
Total/Avg	29503.0	63920	461561
HHDT Estimated Lifetime VMT [1]			600000
		Ratio	0.77
HHDT Annual VMT			57136
Corrected Transit Annual VMT/Vehicle			44000

[1] Transit data taken from Reference 7.

Table 19

Commercial Bus Annual VMT per Vehicle

Year	Fleet VMT (Millions)	New Sales	VMT/Sales
1975	1122.0	4472	250894
1976	1317.6	4033	326705
1977	1313.7	2145	612448
1978	1454.5	3501	415452
1979	1491.4	3199	466208
1980	1822.8	3612	504651
1981	1855.4	3166	586039
1982	1908.2	2458	776322
1983	1970.2	3224	611104
Total/Avg	14255.8	29810	478222
HHDT Estimated Lifetime VMT [1]			600000
		Ratio	0.797
HHDT Annual VMT			57136
Corrected Transit Annual VMT/Vehicle			45500

Bus data taken from Reference 6.

Table 20

School Bus Annual VMT per Vehicle

Year	Fleet VMT (Millions)	New Sales	VMT/Sales
1975	2500	32921	75939
1976	2862	29129	98253
1977	2950	28915	102023
1978	2991	28645	104416
1979	2980	27273	109266
1980	2900	28532	101640
1981	2875	21017	136794
1982	3062	22270	137494
1983	3098	21356	145065
Total/Avg	26218	240058	109215
HHDT Estimated Lifetime VMT [1]			600000
		Ratio	0.182
HHDT Annual VMT			57136
Corrected Transit Annual VMT/Vehicle			10400

Bus data taken from Reference 6.

Table 21
ANNUAL VMT PER VEHICLE (In Thousands)
DIESEL TRUCKS

Year	Class2B	Class3	Class4	Class5	Class6	Class7	Class8A	Class8B	Transit	Commercial	School
62	NS	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
63	16.8	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
64	16.8	20.6	17.4	20.4	21.0	25.7	35.2	58.7	44.0	45.5	10.4
65	16.8	20.6	16.0	18.6	19.0	25.7	35.2	58.7	44.0	45.5	10.4
66	15.7	20.6	15.2	17.5	19.4	25.7	35.2	58.7	44.0	45.5	10.4
67	16.8	20.6	14.7	17.0	19.9	25.7	35.2	58.7	44.0	45.5	10.4
68	16.8	20.6	17.4	20.4	20.6	25.7	35.2	58.7	44.0	45.5	10.4
69	NS	20.6	18.5	22.1	21.3	25.7	35.2	58.7	44.0	45.5	10.4
70	NS	20.6	18.5	22.1	22.1	25.7	35.2	58.7	44.0	45.5	10.4
71	NS	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
72	NS	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
73	NS	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
74	NS	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
75	NS	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
76	NS	20.6	18.5	22.1	22.5	25.7	35.2	58.7	44.0	45.5	10.4
77	16.8	NS	NS	NS	19.4	25.6	34.9	58.2	44.0	45.5	10.4
78	NS	NS	NS	NS	18.9	24.9	34.2	58.2	44.0	45.5	10.4
79	11.7	NS	NS	NS	15.7	25.0	33.6	58.2	44.0	45.5	10.4
80	11.6	NS	NS	NS	14.4	25.2	32.9	58.2	44.0	45.5	10.4
81	11.5	NS	NS	NS	13.6	25.4	32.3	58.2	44.0	45.5	10.4
82	11.5	NS	NS	NS	13.1	25.5	31.6	58.2	44.0	45.5	10.4
83	11.5	NS	NS	NS	13.0	24.8	29.9	58.2	44.0	45.5	10.4
84	11.5	NS	NS	NS	12.1	25.4	29.9	58.2	44.0	45.5	10.4
85	11.5	NS	NS	NS	11.5	24.6	29.6	58.2	44.0	45.5	10.4
86	11.5	NS	NS	NS	11.8	24.8	29.5	58.2	44.0	45.5	10.4
87	11.5	NS	NS	NS	11.4	24.5	29.3	58.2	44.0	45.5	10.4
88	11.5	NS	NS	NS	11.3	24.3	29.2	58.2	44.0	45.5	10.4
89	11.5	NS	NS	NS	11.3	24.2	29.1	58.2	44.0	45.5	10.4
90	11.5	NS	NS	NS	11.2	24.1	29.1	58.2	44.0	45.5	10.4
91	11.5	NS	NS	NS	11.1	23.9	29.1	58.2	44.0	45.5	10.4
92	11.5	NS	NS	NS	11.1	23.8	29.1	58.2	44.0	45.5	10.4
93	11.5	NS	NS	NS	11.0	23.7	29.1	58.2	44.0	45.5	10.4
94	11.5	NS	NS	NS	11.0	23.7	29.1	58.2	44.0	45.5	10.4
95	11.5	NS	NS	NS	11.0	23.6	29.1	58.2	44.0	45.5	10.4
96	11.5	NS	NS	NS	10.9	23.5	29.1	58.2	44.0	45.5	10.4
97	11.5	NS	NS	NS	10.9	23.5	29.1	58.2	44.0	45.5	10.4
98	11.5	NS	NS	NS	10.9	23.5	29.1	58.2	44.0	45.5	10.4
99	11.5	NS	NS	NS	10.9	23.5	29.1	58.2	44.0	45.5	10.4
2000	11.5	NS	NS	NS	10.9	23.5	29.1	58.2	44.0	45.5	10.4

Table 22
ANNUAL VMT PER VEHICLE
(In Thousands)
GASOLINE TRUCKS

Year	Class2B	Class3	Class4	Class5	Class6	Class7	Class8A	Class8B	Transit	Commercial	School
62	11.3	8.7	8.1	7.2	9.6	15.7	19.9	57.7	44.0	45.5	10.4
63	11.3	8.6	8.1	7.2	9.3	15.5	19.3	57.5	44.0	45.5	10.4
64	11.3	8.6	8.1	7.2	9.1	15.4	18.9	57.4	44.0	45.5	10.4
65	11.3	8.5	8.1	7.2	9.1	15.3	18.6	57.2	44.0	45.5	10.4
66	11.3	8.5	8.1	7.2	9.1	15.9	20.5	57.0	44.0	45.5	10.4
67	11.3	8.5	8.1	7.2	9.1	16.4	22.0	56.8	44.0	45.5	10.4
68	11.3	8.6	8.1	7.2	9.1	16.6	22.6	56.3	44.0	45.5	10.4
69	11.3	8.7	8.1	7.3	9.1	16.9	23.1	55.2	44.0	45.5	10.4
70	11.3	8.8	8.2	7.4	9.1	17.0	23.6	52.6	44.0	45.5	10.4
71	11.3	8.8	8.2	7.4	9.4	16.9	23.4	52.7	44.0	45.5	10.4
72	11.3	8.8	8.2	7.4	9.7	16.9	23.1	52.7	44.0	45.5	10.4
73	11.3	8.8	8.2	7.4	9.7	16.4	21.9	52.9	44.0	45.5	10.4
74	11.3	8.8	8.2	7.4	9.6	15.8	20.4	53.0	44.0	45.5	10.4
75	11.3	8.8	8.2	7.4	9.6	15.2	18.5	53.0	44.0	45.5	10.4
76	11.3	8.8	8.2	7.4	9.2	13.8	12.9	47.2	44.0	45.5	10.4
77	11.3	8.9	8.3	7.5	9.1	12.2	9.4	NS	44.0	45.5	10.4
78	11.3	8.9	8.3	7.5	9.1	12.0	9.2	NS	44.0	45.5	10.4
79	11.3	8.9	8.3	7.5	8.9	12.1	8.8	NS	44.0	45.5	10.4
80	11.3	8.9	8.3	7.5	8.9	12.1	8.8	NS	44.0	45.5	10.4
81	11.3	8.9	8.3	7.5	8.6	12.1	8.6	NS	44.0	45.5	10.4
82	11.3	8.9	8.3	7.5	8.3	12.2	8.6	NS	44.0	45.5	10.4
83	11.3	8.9	8.3	7.5	8.2	12.0	8.6	NS	44.0	45.5	10.4
84	11.3	8.9	8.3	7.5	8.2	12.1	8.6	NS	44.0	45.5	10.4
85	11.3	8.9	8.3	7.5	8.2	12.0	8.6	NS	44.0	45.5	10.4
86	11.3	8.9	8.3	7.5	8.2	12.0	8.6	NS	44.0	45.5	10.4
87	11.3	8.9	8.3	7.5	8.2	12.0	8.6	NS	44.0	45.5	10.4
88	11.3	8.9	8.3	7.5	8.2	11.9	8.6	NS	44.0	45.5	10.4
89	11.3	8.9	8.3	7.5	8.2	11.9	NS	NS	44.0	45.5	10.4
90	11.3	8.9	8.3	7.5	8.2	11.8	NS	NS	44.0	45.5	10.4
91	11.3	8.9	8.3	7.5	8.2	11.8	NS	NS	44.0	45.5	10.4
92	11.3	8.9	8.3	7.5	8.2	11.7	NS	NS	44.0	45.5	10.4
93	11.3	8.9	8.3	7.5	8.2	11.7	NS	NS	44.0	45.5	10.4
94	11.3	8.9	8.3	7.5	8.2	11.7	NS	NS	44.0	45.5	10.4
95	11.3	8.9	8.3	7.5	8.2	11.6	NS	NS	44.0	45.5	10.4
96	11.3	8.9	8.3	7.5	8.2	11.6	NS	NS	44.0	45.5	10.4
97	11.3	8.9	8.3	7.5	8.2	11.6	NS	NS	44.0	45.5	10.4
98	11.3	8.9	8.3	7.5	8.2	11.6	NS	NS	44.0	45.5	10.4
99	11.3	8.9	8.3	7.5	8.2	11.6	NS	NS	44.0	45.5	10.7
2000	11.3	8.9	8.3	7.5	8.2	11.6	NS	NS	44.0	45.5	10.4

year urban travel fractions, and could not easily be used to determine model year specific values. As a result, although it is a more accurate measurement of the actual urban travel fraction than was assumed from the TIUS data, it still has inherent inaccuracies due to model year specific effects which cannot be accounted for. But since the model year to model year variation tended to be rather small, the accuracy of measurement is thought to be of greater importance. The urban travel fractions for both gasoline and diesel vehicles are shown in Table 23. The urban travel fractions estimated by MOBILE3 and shown in Tables A-1 and A-3 tended to be significantly lower for diesel vehicles and significantly greater for gasoline vehicles. Although this difference is significant, it has only a small affect on the fleet weighted conversion factors since gasoline and diesel vehicles are weighted separately.

V. Summary of Results

The fleet-average emission conversion factors (in units of BHP-hr/mi) used in MOBILE4 are listed in Table 1. MOBILE4 class-specific conversion factors are listed in Tables 5 and 6. The non-engine-related fuel economy improvements detailed in Tables 8 through 10, and summarized in Table 11, were applied to the 1982 class-specific conversion factors to develop the post-1982 class-specific conversion factors. The past and future class-specific conversion factors were weighted by urban vehicle miles travelled to calculate the fleet average conversion factors. The weighting factors used are detailed in Tables 13 and 14. Figure 1 illustrates the comparison between the MOBILE3 and MOBILE4 historic and future gasoline and diesel fleet average conversion factors.

The projected future fleet-average conversion factors show a steady decrease as time goes on due to increased fuel economy. Diesel conversion factors decrease more rapidly than gasoline conversion factors. Current MOBILE4 fleet average conversion factors are lower than those projected by MOBILE3. This arises mainly due to the fact that Class 2B diesel sales have increased, and gasoline sales in the heavier classes have decreased, causing heavier weighting of vehicles with lower conversion factors.

VII. Recommendations

The future gasoline and diesel conversion factors presented here are based on estimates and projections. There are several areas where the present degree of uncertainty is fairly high and where further data could significantly reduce the uncertainty of the results.

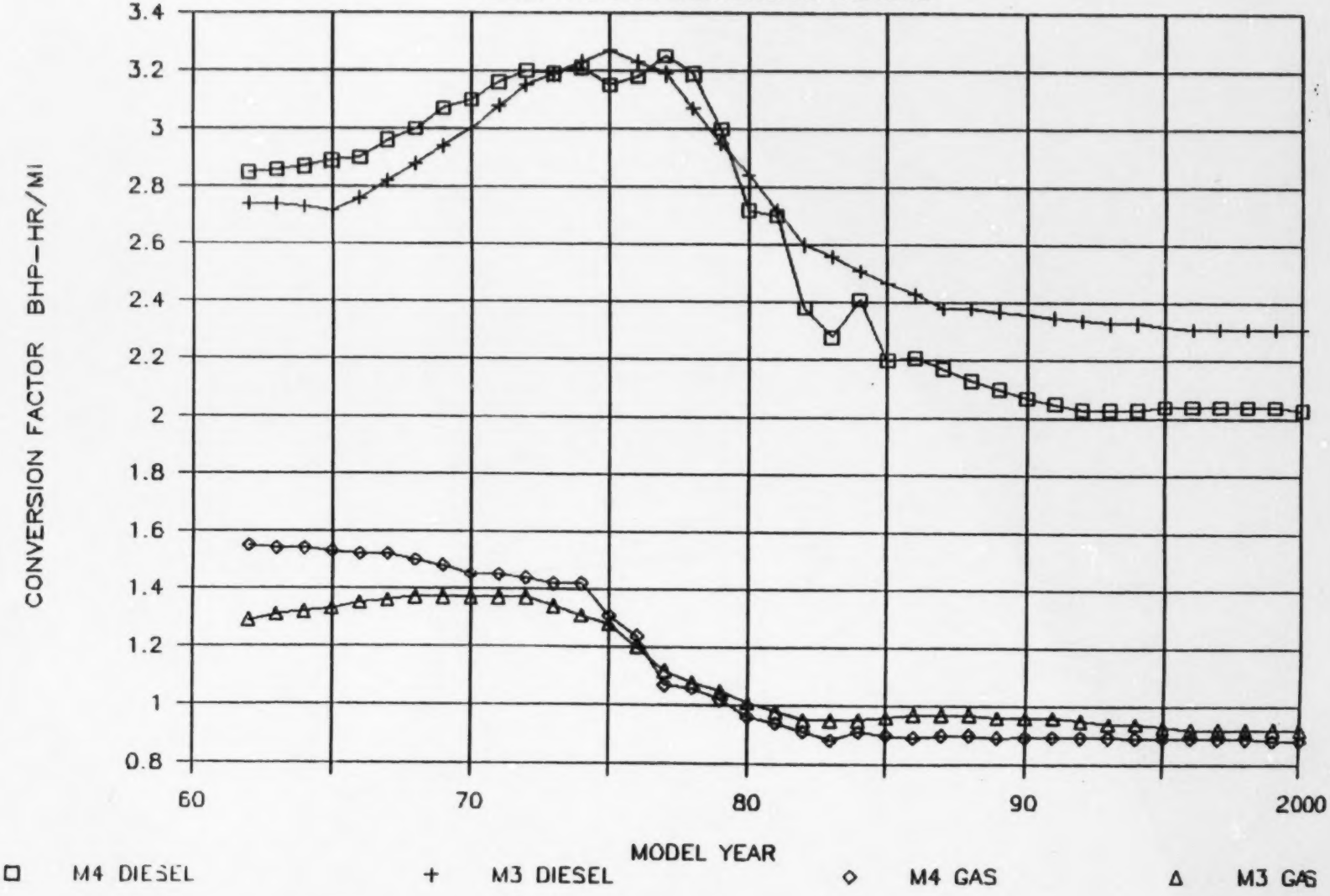
Table 23

Urban Travel Fractions [10]

Vehicle Class	Gasoline	Diesel
Class 2B	0.45	0.64
Class 3	0.44	0.45
Class 4	0.44	0.45
Class 5	0.44	0.45
Class 6	0.31	0.53
Class 7	0.46	0.51
Class 8A	0.25	0.42
Class 8B	0.08	0.26
Transit	1.00	1.00
Commercial	0.26	0.26
School	0.34	0.34

FIGURE 1

FLEET AVERAGE CONVERSION FACTORS



The most important area of concern is fuel economy. Better documented data on current urban fuel economy is needed, since the TIUS only addresses nationwide fuel economy and the accuracy of the submittals by surveyees is unknown. Equally important is the need for further information on the effects of future technology on urban fuel economy improvements. This is the main factor in projecting future conversion factors, assuming fuel density will not change significantly in the next 25 years. The urban fuel economy impact of technological developments in areas such as radial tires, lubrication, aerodynamic drag reduction, and speed control are not well known and the penetration of these technologies into the heavy-duty vehicle market is quite dependent on future fuel prices and manufacturers' marketing strategies. Any new data in these areas will be very useful in improving future projections of the emission conversion factors.

In addition, as was mentioned earlier, any future conversion factor work should attempt to address the question of whether the fuel economy of a given model year fleet remains essentially constant with time as is assumed in this analysis. The 1982 TIUS resulted in significantly lower fuel economy estimates for pre-1978 vehicles than had the 1977 TIUS suggesting that this assumption may not be correct.

A second important area for further study is the estimation of the urban VMT fraction for the various classes of heavy-duty vehicles. The TIUS information used in the MOBILE3 analysis yields only a surrogate for urban VMT fraction. On the other hand, the UMTRI information used in this analysis is not model-year specific. Information with the accuracy of the UMTRI data, yet with the capability to be made model year specific, as with the TIUS data, would provide the optimum information.

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13. Historical and Projected Emissions Conversion Factor and Fuel Economy for Heavy-Duty Trucks 1962-2002, prepared for Motor Vehicle Manufacturers Association by Energy and Environmental Analysis, Inc., 1655 N. Fort Mayer Drive, Arlington, Virginia 22209, December 1983.

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Appendix A

MOBILE3 Data

Table A-1

MOBILE3 Pre-1978 Data

Vehicle Class	Year	Gas Annual VMT	Diesel Annual VMT	Gas Urban Fraction	Diesel Urban Fraction	Gas Fuel Economy	Diesel Fuel Economy	Gas BSFC	Diesel BSFC	Sales Fraction	Diesel Fraction	Gasoline Conversion Factor	Diesel Conversion Factor
2B	1962	11614	11614	0.69	0.63	10.12	13.12	0.7	0.54	0.06400	0.0000	0.870	0.998
2B	1965	11614	11614	0.69	0.63	10.12	13.12	0.7	0.54	0.08020	0.0020	0.870	0.998
2B	1967	11614	11614	0.69	0.63	10.12	13.12	0.7	0.54	0.09560	0.0030	0.870	0.998
2B	1970	11614	11614	0.69	0.63	10.12	13.12	0.7	0.54	0.12620	0.0010	0.870	0.998
2B	1972	11614	11614	0.69	0.63	10.12	13.12	0.7	0.54	0.13200	0.0000	0.870	0.998
2B	1975	11614	11614	0.69	0.63	10.12	13.12	0.7	0.54	0.28000	0.0000	0.870	0.998
2B	1977	11614	11614	0.69	0.63	10.12	13.12	0.7	0.54	0.34800	0.0010	0.870	0.998
3-5	1962	9832	18883	0.68	0.55	7.60	8.11	0.7	0.51	0.44630	0.0139	0.870	0.998
3-5	1965	9832	18883	0.68	0.55	7.42	8.11	0.7	0.51	0.38160	0.0255	1.158	1.710
3-5	1967	9832	18883	0.68	0.55	7.36	8.11	0.7	0.51	0.30530	0.0306	1.180	1.710
3-5	1970	9832	18883	0.68	0.55	7.22	8.11	0.7	0.51	0.22490	0.0031	1.198	1.710
3-5	1972	9832	18883	0.68	0.55	7.11	8.11	0.7	0.51	0.21600	0.0028	1.219	1.710
3-5	1975	9832	18883	0.68	0.55	7.40	8.11	0.7	0.51	0.10600	0.0047	1.238	1.710
3-5	1977	9832	18883	0.68	0.56	7.63	8.11	0.7	0.51	0.07100	0.0000	1.190	1.710
6	1962	9734	22187	0.66	0.42	6.37	8.25	0.7	0.50	0.25170	0.0420	1.154	1.710
6	1965	9734	22187	0.66	0.42	6.13	8.25	0.7	0.50	0.23490	0.1050	1.129	1.710
6	1967	9734	22187	0.66	0.42	5.95	8.25	0.7	0.50	0.28660	0.0940	1.382	1.714
6	1970	9734	22187	0.66	0.42	5.75	8.25	0.7	0.49	0.28320	0.0760	1.438	1.714
6	1972	9734	22187	0.66	0.42	5.60	8.25	0.7	0.47	0.30400	0.0310	1.480	1.714
6	1975	9734	22187	0.66	0.43	5.50	8.25	0.7	0.46	0.33500	0.0410	1.531	1.749
6	1977	9734	22187	0.66	0.43	5.60	8.40	0.7	0.45	0.24500	0.1000	1.572	1.824
7	1962	11223	25883	0.63	0.35	5.62	6.60	0.7	0.49	0.10150	0.4310	1.601	1.864
7	1965	11223	25883	0.63	0.35	5.50	6.60	0.7	0.49	0.09430	0.4470	1.572	1.871
7	1965	11223	25883	0.63	0.34	5.37	6.60	0.7	0.48	0.09600	0.3790	1.564	1.860
7	1970	11223	25883	0.63	0.33	5.23	6.60	0.7	0.47	0.09980	0.3330	1.567	2.187
7	1972	11223	25883	0.63	0.33	5.15	6.60	0.7	0.47	0.07600	0.3480	1.601	2.187
7	1975	11223	25883	0.63	0.35	5.05	6.70	0.7	0.46	0.06700	0.4490	1.640	2.232
7	1977	11223	25883	0.63	0.38	5.10	6.93	0.7	0.45	0.05900	0.5780	1.683	2.280

Table A-1 continued

Vehicle Class	Year	Gas Annual VMT	Diesel Annual VMT	Gas Urban Fraction	Diesel Urban Fraction	Gas Fuel Economy	Diesel Fuel Economy	Gas BSFC	Diesel BSFC	Sales Fraction	Diesel Fraction	Gasoline Conversion Factor	Diesel Conversion Factor
8	1962	18413	46853	0.54	0.23	4.57	6.15	0.7	0.49	0.13140	0.5530	1.710	2.280
8	1965	16997	50694	0.59	0.21	4.43	6.04	0.7	0.49	0.19580	0.6850	1.743	2.295
8	1967	16997	58094	0.59	0.21	4.35	4.96	0.7	0.48	0.21630	0.7310	1.726	2.268
8	1970	16247	55155	0.60	0.20	4.20	4.88	0.7	0.47	0.26570	0.8440	1.710	2.198
8	1972	16763	66971	0.62	0.20	4.10	4.82	0.7	0.46	0.26600	0.8820	1.927	2.802
8	1975	16660	66172	0.63	0.20	4.05	4.82	0.7	0.45	0.19800	0.8940	1.987	2.864
8	1977	15560	55785	0.63	0.20	4.15	4.91	0.7	0.43	0.27300	0.9610	2.024	2.970
Bus	1962	0	45000	0.00	1.00	3.68	3.68	0.7	0.48	0.00600	1.0000	2.096	3.083
Bus	1965	0	45000	0.00	1.00	3.68	3.68	0.7	0.48	0.00600	1.0000	2.147	3.190
Bus	1967	0	45000	0.00	1.00	3.68	3.68	0.7	0.48	0.00600	1.0000	2.174	3.260
Bus	1970	0	45000	0.09	1.00	3.68	3.68	0.7	0.48	0.00600	1.0000	2.122	3.350
Bus	1972	0	45000	0.00	1.00	3.68	3.68	0.7	0.48	0.00600	1.0000	2.072	3.296
Bus	1975	0	45000	0.00	1.00	3.68	3.68	0.7	0.48	0.00600	1.0000	2.392	4.004
Bus	1977	0	45000	0.00	1.00	3.68	3.68	0.7	0.48	0.00449	1.0000	2.392	4.004

Table A-2

MOBILE3 Post-1977 Class Specific Conversion Factors

Class	1982	1987	1992	1997
Diesel				
2B-5	0.970	0.964	0.944	0.922
6	1.865	1.776	1.765	1.746
7	2.260	2.154	2.141	2.115
8A	3.002	2.863	2.849	2.811
8B	3.190	3.385	3.106	3.048
Bus	3.989	3.802	3.782	3.733
Gasoline				
2B-5	0.845	0.840	0.823	0.804
6	1.536	1.484	1.456	1.427
7	1.690	1.634	1.613	1.569
8A	2.083	2.012	1.958	1.926

Table A-3

MOBILE3 Post-1977 Input Data

Vehicle Class	Year	Gas VMT	Diesel VMT	Gas Urban Fraction	Diesel Urban Fraction	Sales Fraction	Diesel Fraction
2B-5	1977	11614	11614	0.069	0.630	0.419	0.000
2B-5	1982	11614	11614	0.687	0.633	0.666	0.162
2B-5	1987	11614	11614	0.697	0.633	0.600	0.250
2B-5	1992	11614	11614	0.703	0.633	0.580	0.300
2B-5	1997	11614	11614	0.710	0.633	0.576	0.300
6	1977	9734	22188	0.660	0.428	0.245	0.100
6	1982	9734	19115	0.687	0.447	0.050	0.377
6	1987	9734	18826	0.743	0.452	0.049	0.430
6	1992	9734	18826	0.779	0.456	0.048	0.500
6	1997	9734	18545	0.829	0.473	0.050	0.550
7	1977	11223	25883	0.630	0.377	0.059	0.578
7	1982	11223	25697	0.681	0.385	0.116	0.580
7	1987	11223	25250	0.723	0.387	0.168	0.600
7	1992	11223	24634	0.735	0.392	0.168	0.650
7	1997	11223	23488	0.775	0.396	0.165	0.700
8A	1977	15560	29950	0.630	0.358	0.032	0.770
8A	1982	15560	27037	0.728	0.359	0.014	0.889
8A	1987	15560	27037	0.850	0.359	0.014	0.875
8A	1992	15560	26393	0.850	0.366	0.017	0.941
8A	1997	15560	25779	0.850	0.394	0.017	1.000
8B	1977	0	62500	0.000	0.176	0.241	1.000
8B	1982	0	62500	0.000	0.176	0.140	1.000
8B	1987	0	62500	0.000	0.176	0.161	1.000
8B	1992	0	62500	0.000	0.176	0.180	1.000
8B	1997	0	62500	0.000	0.176	0.184	1.000
Bus	1977	0	45000	0.000	1.000	0.004	1.000
Bus	1982	0	45000	0.000	1.000	0.011	1.000
Bus	1987	0	45000	0.000	1.000	0.008	1.000
Bus	1992	0	45000	0.000	1.000	0.008	1.000
Bus	1997	0	45000	0.000	1.000	0.008	1.000

Appendix B

UMTRI Survey of
Percent Penetration of Fuel
Economy Improvement Devices
Into Diesel Fleet by Model Year[11]

Model	Aero Body		Aero Add-on		Radial Tires		Variable Fan		Governor	
Year	MHDT	HHDT	MHDT	HHDT	MHDT	HHDT	MHDT	HHDT	MHDT	HHDT
68	0.0	5.4	6.9	10.1	32.0	48.0	10.9	15.5	19.4	28.9
69	0.0	5.1	0.0	0.0	22.7	26.3	11.3	10.9	20.7	21.2
70	0.0	0.0	0.0	10.4	27.0	27.1	6.9	12.0	21.5	29.8
71	3.4	0.0	3.4	1.7	29.5	25.8	29.3	5.0	11.2	12.3
72	0.0	1.3	0.0	2.1	36.5	41.1	14.9	12.2	18.8	23.6
73	0.0	0.0	0.0	6.5	39.9	43.2	12.2	15.7	17.1	22.1
74	0.0	0.7	1.5	5.0	47.2	39.4	20.2	15.5	22.5	19.6
75	6.3	2.3	0.0	5.7	36.4	46.5	14.0	14.7	19.0	17.3
76	8.2	4.9	0.0	9.7	51.4	57.7	25.7	26.0	22.0	22.1
77	5.1	2.3	1.4	8.5	41.0	53.9	28.6	33.6	22.8	19.5
78	5.9	6.2	1.8	9.6	48.6	60.1	28.6	43.4	30.3	23.2
79	15.8	7.5	4.2	9.3	44.1	57.0	36.7	42.6	24.2	20.6
80	10.6	10.1	5.7	13.5	50.4	64.5	32.2	56.9	28.8	22.8
81	14.8	12.8	6.3	22.2	45.4	65.9	28.9	46.8	23.2	30.5
82	15.4	19.9	1.9	29.1	57.3	74.4	32.3	62.6	29.5	33.9
83	15.5	28.2	6.0	25.4	58.5	77.4	26.9	58.9	27.7	32.0

Appendix C:

Computer Program Used to Calculate the Future Non-Engine Related Fuel Economy Improvements

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THIS IS A PROGRAM THAT CALCULATES FUEL ECONOMY
IMPROVEMENTS TO BE USED IN CALCULATING FUTURE
CONVERSION FACTORS FOR EMISSIONS (IN G/BHP-HR)

INPUT FILES ARE "8=...DIESCB.DAT
                     DIES6.DAT
                     DIES7.DAT
                     DIES8A.DAT
                     DIES8B.DAT
FOR DIESEL FUEL ECONOMY IMPROVEMENTS
AND                ...GASCB.DAT
                     GAS7.DAT
                     GAS4.DAT
                     GAS5.DAT
                     GAS6.DAT
                     GAS7.DAT
                     GAS8A.DAT
FOR GASOLINE FUEL ECONOMY IMPROVEMENTS

OUTPUT FILES ARE "7=...DIESCB.OUT.DIES6.OUT....FOR DIESEL
                 "7=...GASCB.OUT.GAS7.OUT....FOR GASOLINE

VFURB=THE FRACTION OF VEHICLES CLASSIFIED FOR EACH MY AS LOCAL
VFSR=THE FRACT. OF VEH. CLASSIFIED FOR EACH MY AS SHORT RANGE
VFLR=THE FRACT. OF VEH. CLASSIFIED FOR EACH MY AS LONG RANGE
PFFEI=THE PERCENT FUEL ECONOMY IMPROVEMENT ASSUMED TO A
      VEHICLE FOR THE IMPROVEMENT TYPE IN QUESTION
PFLAFF=THE % OF THE FLEET AFFECTED BY THE IMPROVEMENT TYPE
       (PENETRATION INTO THE MARKET)
IMP=THE BASE YEAR PENETRATION INTO THE MARKET OF THE
    IMPROVEMENT TYPE
DESCR=THE DESCRIPTION OF THE IMPROVEMENT TYPE
ITYPE=THE INTEGER IDENTIFYING THE IMPROVEMENT TYPE
VMTFUR=WEIGHTED VEHICLE FRACTION URBAN TO ACCOUNT FOR OPERATION
       OUTSIDE OF ITS PRIMARY USE AREA
VMTFSR=WEIGHTED VEHICLE FRACTION FOR SHORT RANGE
VMTFLR=WEIGHTED VEHICLE FRACTION FOR LONG RANGE
*=FRACTION OF VEHICLES URBAN WITH PRIMARY USE LOCAL
*=FRACTION OF VEHICLES URBAN WITH PRIMARY USE SHORT RANGE
I=FRACTION OF VEHICLES URBAN WITH PRIMARY USE LONG RANGE
UFFAFF=THE % OF THE URBAN VEHICLES WHICH ARE AFFECTED BY AN
       IMPROVEMENT TYPE
PFASR=THE PERCENT OF THE SHORT RANGE FLEET WHICH ARE AFFECTED
       BY AN IMPROVEMENT TYPE
PFAURB=THE % OF URBAN VEHICLES WHICH HAVE THEIR PRIMARY USE
       IN URBAN AREAS WHICH ARE AFFECTED BY THE IMPROVEMENT
       TYPE
TTLFEI=THE FUEL ECONOMY IMPROVEMENT TO THE CLASS DUE TO AN
       INDIVIDUAL IMPROVEMENT TYPE
TOTFEI=THE FUEL ECONOMY IMPROVEMENT TO THE CLASS DUE TO AN
       INDIVIDUAL IMPROVEMENT TYPE
DIFF=THE DIFFERENCE IN THE FUEL ECONOMY IMPROVEMENT OF EACH
       IMPROVEMENT TYPE BETWEEN THE CURRENT YEAR AND THE
       PREVIOUS YEAR
DIFSUM=THE DIFFERENCE BETWEEN THE SUM OF THE FUEL ECONOMY
       IMPROVEMENT FOR ALL OF THE IMPROVEMENT TYPES FOR
       THE CURRENT YEAR, AND THE PREVIOUS YEAR


REAL*8 IMP
INTEGER*4 YEAR
CHARACTER*5 DESCR
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      OPEN(7,FILE='   ')

C     INITIALIZE-EVERYTHING TO ZERO

      DO 13 IYEAR=1,4
        DIFSUM(IYEAR)=0.0
          DO 14 ITYPE=1,11
            TOTFEI(IYEAR,ITYPE)=0.0
            DIFF(IYEAR,ITYPE)=0.0
   14     CONTINUE
   13 CONTINUE

      WRITE (6,250)

      PFASR=0.0
      PFAURB=0.0

  250 FORMAT(' YEAR   VFURB  VFSR    VFLR  PERFEI PFLAFF  VFLR
     *PFASR  PFAURB UPFAFF VMTFEI IMPRV')

C     READ IN THE DATA FROM THE DATA FILE

      READ(8,*,END=500) YEAR,IYEAR,VFURB,VFSR,VFLR,PERFEI,PFLAFF,
     *  IMP,DESCR,ITYPE

C     WEIGHT THE VEHICLE FRACTIONS TO ACCOUNT FOR OTHER THAN
C           PRIMARY USE

      VMTFUR=.85*VFURB+.075*VFSR+.075*VFLR
      VMTFSR=.85*VFSR+.075*VFURB+.075*VFLR
      VMTFLR=.85*VFLR+.075*VFURB+.075*VFSR

C     DETERMINE THE FRACTIONS OF URBAN VEHICLES FROM EACH SUBCLASS

      X=.85*VFURB/VMTFUR
      Y=.075*VFSR/VMTFUR
      Z=.075*VFLR/VMTFUR

C     DETERMINE THE PERCENT OF THE URBAN FLEET AFFECTED BY THE
C     FUEL ECONOMY IMPROVEMENT IF ONLY LONG RANGE VEHICLES ARE
C     AFFECTED

      IF (PFLAFF.LE.VFLR) UPFAFF=PFLAFF+.075/VMTFUR
      IF (PFLAFF.LE.VFLR) GO TO 10

C     DETERMINE THE PERCENT OF THE URBAN FLEET AFFECTED BY THE FUEL
C     ECONOMY IMPROVEMENT IF ONLY LONG AND SHORT RANGE VEHICLES ARE
C     AFFECTED

      PFASR=PFLAFF-VFLR
      IF (PFASR.LE.VFSR)  UPFAFF=Z+PFASR+.075/VMTFUR
      IF (PFASR.LE.VFSR) GO TO 10

C     DETERMINE THE PERCENT OF THE URBAN FLEET AFFECTED BY THE FUEL
C     ECONOMY IMPROVEMENT IF LONG RANGE SHORT RANGE AND LOCAL
C     VEHICLES ARE AFFECTED

      PFAURB=PFASR-VFSR
      UPFAFF=Z+Y+PFAURB+.85/VMTFUR

C     DETERMINE THE FUEL ECONOMY IMPROVEMENT TO THE ENTIRE FLEET
```

```
      TOTFEI(IYEAR,ITYPE)=PERFEI*UPFAFF
C
C     DETERMINE THE FUEL ECONOMY IMPROVEMENT CALCULATED FOR THE
C     BASE YEAR
C
      DO 15 ITYPE=1,11
        DIFF(1,ITYPE)=TOTFEI(1,ITYPE)
15    CONTINUE
C
C     DETERMINE THE DIFFERENCE BETWEEN THE FUEL ECONOMY IMPROVEMENT
C     FOR THE CLASS, YEAR AND IMPROVEMENT TYPE IN QUESTION, AND THAT
C     OF THE PREVIOUS YEAR
C
      DO 16 IYEAR=2,5
        DO 17 ITYPE=1,11
          IF (TOTFEI(IYEAR,ITYPE).EQ.0.0) DIFF(IYEAR,ITYPE)=0.0
          IF (TOTFEI(IYEAR,ITYPE).EQ.0.0) GO TO 17
C
          DIFF(IYEAR,ITYPE)=TOTFEI(IYEAR,ITYPE)-TOTFEI(IYEAR-1,ITYPE)
17      CONTINUE
16    CONTINUE
C
C     DETERMINE THE DIFFERENCE BETWEEN THE TOTAL FUEL ECONOMY
C     IMPROVEMENT FOR THE CLASS RESULTING FROM ALL OF THE FUEL
C     ECONOMY IMPROVEMENT TYPES FOR THE YEAR IN QUESTION, AND
C     THAT OF THE PREVIOUS YEAR
C
      DO 18 IYEAR=1,5
        DIFSUM(IYEAR)=0.0
        DO 19 ITYPE=1,11
          DIFSUM(IYEAR)=DIFSUM(IYEAR)+DIFF(IYEAR,ITYPE)
19      CONTINUE
18    CONTINUE
C
      WRITE(6,220)YEAR,VFURB,VFSR,VFLR,PERFEI,PFLAFF,VFLR,PFASR,
     1  PFAURB,UPFAFF,TTLFEI,IMP
      GO TO 5
C
220   FORMAT(1X,A4,1X,10F7.2,A8)
100   FORMAT(1X,A4,1X,I4,3F6.1,3X,A8,I4)
C
300   WRITE(6,300) DIFSUM(1),DIFSUM(2),DIFSUM(3),DIFSUM(4),DIFSUM(5)
300   FORMAT(5F12.3)
C
500   WRITE(7,300)DIFSUM(1),DIFSUM(2),DIFSUM(3),DIFSUM(4),DIFSUM(5)
C
      STOP
      END
```

1982	1	78.0	13.5	8.5	5.0	10.0	10.0	'MANODR'	6
1982	1	78.0	13.5	8.5	1.4	55.0	55.0	'RADIAL'	8
1983	2	78.0	13.5	8.5	1.5	7.0	0.0	'DRVLUB'	2
1983	2	78.0	13.5	8.5	5.0	3.0	0.0	'AUTODR'	5
1983	2	78.0	13.5	8.5	5.0	12.0	10.0	'MANODR'	6
1983	2	78.0	13.5	8.5	1.4	58.0	55.0	'RADIAL'	8
1984	3	78.0	13.5	8.5	1.5	13.0	0.0	'DRVLUB'	2
1984	3	78.0	13.5	8.5	5.0	6.0	0.0	'AUTODR'	5
1984	3	78.0	13.5	8.5	5.0	14.0	10.0	'MANODR'	6
1984	3	78.0	13.5	8.5	1.4	61.0	55.0	'RADIAL'	8
1985	4	78.0	13.5	8.5	1.5	20.0	0.0	'DRVLUB'	2
1985	4	78.0	13.5	8.5	5.0	10.0	0.0	'AUTODR'	5
1985	4	78.0	13.5	8.5	5.0	16.0	10.0	'MANODR'	6
1985	4	78.0	13.5	8.5	1.4	64.0	55.0	'RADIAL'	8
1986	5	78.0	13.5	8.5	1.5	27.0	0.0	'DRVLUB'	2
1986	5	78.0	13.5	8.5	5.0	13.0	0.0	'AUTODR'	5
1986	5	78.0	13.5	8.5	5.0	18.0	10.0	'MANODR'	6
1986	5	78.0	13.5	8.5	1.4	67.0	55.0	'RADIAL'	8

1982	1	62.9	31.8	5.3	2.5	5.0	5.0	'AERO'	4
1982	1	62.9	31.8	5.3	3.0	14.0	14.0	'RADIAL'	8
1982	1	62.9	31.8	5.3	5.3	50.0	50.0	'FANDRV'	10
1982	1	62.9	31.8	5.3	6.0	4.0	4.0	'SPEEDC'	11
1983	2	62.9	32.1	5.0	2.5	5.0	5.0	'AERO'	4
1983	2	62.9	32.1	5.0	3.0	14.0	14.0	'RADIAL'	8
1983	2	62.9	32.1	5.0	1.5	7.0	0.0	'DRVLUB'	2
1983	2	62.9	32.1	5.0	6.0	1.0	0.0	'ADVRAD'	9
1983	2	62.9	32.1	5.0	5.3	60.0	50.0	'FANDRV'	10
1983	2	62.9	32.1	5.0	6.0	4.0	4.0	'SPEEDC'	11
1984	3	69.6	26.4	4.0	2.5	6.0	5.0	'AERO'	4
1984	3	69.6	26.4	4.0	3.0	14.0	14.0	'RADIAL'	8
1984	3	69.6	26.4	4.0	6.0	2.0	0.0	'ADVRAD'	9
1984	3	69.6	26.4	4.0	1.5	13.0	0.0	'DRVLUB'	2
1984	3	69.6	26.4	4.0	5.3	70.0	50.0	'FANDRV'	10
1984	3	69.6	26.4	4.0	6.0	4.0	4.0	'SPEEDC'	11
1985	4	74.1	22.5	3.4	2.5	6.0	5.0	'AERO'	4
1985	4	74.1	22.5	3.4	3.0	14.0	14.0	'RADIAL'	8
1985	4	74.1	22.5	3.4	6.0	3.0	0.0	'ADVRAD'	9
1985	4	74.1	22.5	3.4	1.5	20.0	0.0	'DRVLUB'	2
1985	4	74.1	22.5	3.4	6.0	5.0	4.0	'SPEEDC'	11
1985	4	74.1	22.5	3.4	5.3	80.0	50.0	'FANDRV'	10
1986	5	71.5	24.7	3.8	2.5	7.0	5.0	'AERO'	4
1986	5	71.5	24.7	3.8	3.0	14.0	14.0	'RADIAL'	8
1986	5	71.5	24.7	3.8	6.0	4.0	0.0	'ADVRAD'	9
1986	5	71.5	24.7	3.8	1.5	27.0	0.0	'DRVLUB'	2
1986	5	71.5	24.7	3.8	6.0	5.0	4.0	'SPEEDC'	11
1986	5	71.5	24.7	3.8	5.3	90.0	50.0	'FANDRV'	10

1982	1	67.9	25.2	6.9	2.5	5.0	5.0	'AERO'	4
1982	1	67.9	25.2	6.9	3.0	14.0	14.0	'RADIAL'	8
1982	1	67.9	25.2	6.9	5.3	50.0	50.0	'FANDRV'	10
1982	1	67.9	25.2	6.9	6.0	4.0	4.0	'SPEEDC'	11
1983	2	67.9	25.2	6.9	2.5	5.0	5.0	'AERO'	4
1983	2	67.9	25.2	6.9	3.0	14.0	14.0	'RADIAL'	8
1983	2	67.9	25.2	6.9	1.5	7.0	0.0	'DRVLUB'	2
1983	2	67.9	25.2	6.9	6.0	1.0	0.0	'ADVRAD'	9
1983	2	67.9	25.2	6.9	5.3	80.0	50.0	'FANDRV'	10
1983	2	67.9	25.2	6.9	6.0	4.0	4.0	'SPEEDC'	11
1984	3	67.9	25.2	6.9	2.5	5.0	5.0	'AERO'	4
1984	3	67.9	25.2	6.9	3.0	14.0	14.0	'RADIAL'	8
1984	3	67.9	25.2	6.9	6.0	2.0	0.0	'ADVRAD'	9
1984	3	67.9	25.2	6.9	1.5	13.0	0.0	'DRVLUB'	2
1984	3	67.9	25.2	6.9	5.3	70.0	50.0	'FANDRV'	10
1984	3	67.9	25.2	6.9	6.0	4.0	4.0	'SPEEDC'	11
1985	4	67.9	25.2	6.9	2.5	6.0	5.0	'AERO'	4
1985	4	67.9	25.2	6.9	3.0	14.0	14.0	'RADIAL'	8
1985	4	67.9	25.2	6.9	6.0	3.0	0.0	'ADVRAD'	9
1985	4	67.9	25.2	6.9	1.5	20.0	0.0	'DRVLUB'	2
1985	4	67.9	25.2	6.9	6.0	5.0	4.0	'SPEEDC'	11
1985	4	67.9	25.2	6.9	5.3	80.0	50.0	'FANDRV'	10
1986	5	67.9	25.2	6.9	2.5	7.0	5.0	'AERO'	4
1986	5	67.9	25.2	6.9	3.0	14.0	14.0	'RADIAL'	8
1986	5	67.9	25.2	6.9	6.0	4.0	0.0	'ADVRAD'	9
1986	5	67.9	25.2	6.9	1.5	27.0	0.0	'DRVLUB'	2
1986	5	67.9	25.2	6.9	6.0	5.0	4.0	'SPEEDC'	11
1986	5	67.9	25.2	6.9	5.3	90.0	50.0	'FANDRV'	10

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1982	1	60.9	23.1	16.0	2.5	5.0	5.0	'AERO'	4
1982	1	60.9	23.1	16.0	3.0	14.0	14.0	'RADIAL'	8
1982	1	60.9	23.1	16.0	5.3	50.0	50.0	'FANDRV'	10
1982	1	60.9	23.1	16.0	6.0	4.0	4.0	'SPEEDC'	11
1983	2	63.9	21.3	14.8	2.5	5.0	5.0	'AERO'	4
1983	2	63.9	21.3	14.8	3.0	14.0	14.0	'RADIAL'	8
1983	2	63.9	21.3	14.8	1.5	7.0	0.0	'DRVLUB'	2
1983	2	63.9	21.3	14.8	6.0	1.0	0.0	'ADVRAD'	9
1983	2	63.9	21.3	14.8	5.3	60.0	50.0	'FANDRV'	10
1983	2	63.9	21.3	14.8	6.0	4.0	4.0	'SPEEDC'	11
1984	3	63.9	21.3	14.8	2.5	5.0	5.0	'AERO'	4
1984	3	63.9	21.3	14.8	3.0	14.0	14.0	'RADIAL'	8
1984	3	63.9	21.3	14.8	6.0	2.0	0.0	'ADVRAD'	9
1984	3	63.9	21.3	14.8	1.5	13.0	0.0	'DRVLUB'	2
1984	3	63.9	21.3	14.8	5.3	70.0	50.0	'FANDRV'	10
1984	3	63.9	21.3	14.8	6.0	4.0	4.0	'SPEEDC'	11
1985	4	64.3	21.1	14.6	2.5	6.0	5.0	'AERO'	4
1985	4	64.3	21.1	14.6	3.0	14.0	14.0	'RADIAL'	8
1985	4	64.3	21.1	14.6	6.0	3.0	0.0	'ADVRAD'	9
1985	4	64.3	21.1	14.6	1.5	20.0	0.0	'DRVLUB'	2
1985	4	64.3	21.1	14.6	6.0	5.0	4.0	'SPEEDC'	11
1985	4	64.3	21.1	14.6	5.3	80.0	50.0	'FANDRV'	10
1986	5	64.6	20.9	14.5	2.5	7.0	5.0	'AERO'	4
1986	5	64.6	20.9	14.5	3.0	14.0	14.0	'RADIAL'	8
1986	5	64.6	20.9	14.5	6.0	4.0	0.0	'ADVRAD'	9
1986	5	64.6	20.9	14.5	1.5	27.0	0.0	'DRVLUB'	2
1986	5	64.6	20.9	14.5	6.0	5.0	4.0	'SPEEDC'	11
1986	5	64.6	20.9	14.5	5.3	90.0	50.0	'FANDRV'	10

```
1982  1  34.3  31.5  34.2  2.5  22.0  22.0  'AERO'     4
1982  1  34.3  31.5  34.2  6.8  65.0  65.0  'RADIAL'   8
1982  1  34.3  31.5  34.2  10.2 1.7   1.7   'ADVRAD'   9
1982  1  34.3  31.5  34.2  6.8  98.0  98.0  'FANDRV'   10
1982  1  34.3  31.5  34.2  5.0  8.0   8.0   'SPEEDC'   11
1983  2  34.3  31.5  34.2  2.5  24.0  22.0  'AERO'     4
1983  2  34.3  31.5  34.2  6.8  62.0  65.0  'RADIAL'   8
1983  2  34.3  31.5  34.2  10.2 5.0   1.7   'ADVRAD'   9
1983  2  34.3  31.5  34.2  6.8  98.0  98.0  'FANDRV'   10
1983  2  34.3  31.5  34.2  5.0  10.0  8.0   'SPEEDC'   11
1983  2  34.3  31.5  34.2  1.5  7.0   0.0   'DRVLUB'   2
1984  3  34.3  31.5  34.2  2.5  27.0  22.0  'AERO'     4
1984  3  34.3  31.5  34.2  6.8  58.0  65.0  'RADIAL'   8
1984  3  34.3  31.5  34.2  10.2 10.0  1.7   'ADVRAD'   9
1984  3  34.3  31.5  34.2  6.8  99.0  98.0  'FANDRV'   10
1984  3  34.3  31.5  34.2  5.0  11.0  8.0   'SPEEDC'   11
1984  3  34.3  31.5  34.2  1.5  13.0  0.0   'DRVLUB'   2
1985  4  34.3  31.5  34.2  2.5  29.0  22.0  'AERO'     4
1985  4  34.3  31.5  34.2  6.8  54.0  65.0  'RADIAL'   8
1985  4  34.3  31.5  34.2  10.2 15.0  1.7   'ADVRAD'   9
1985  4  34.3  31.5  34.2  6.8  99.0  98.0  'FANDRV'   10
1985  4  34.3  31.5  34.2  5.0  13.0  8.0   'SPEEDC'   11
1985  4  34.3  31.5  34.2  1.5  20.0  0.0   'DRVLUB'   2
1986  5  34.3  31.5  34.2  2.5  32.0  22.0  'AERO'     4
1986  5  34.3  31.5  34.2  6.8  50.0  65.0  'RADIAL'   8
1986  5  34.3  31.5  34.2  10.2 20.0  1.7   'ADVRAD'   9
1986  5  34.3  31.5  34.2  6.8  100.0 98.0  'FANDRV'   10
1986  5  34.3  31.5  34.2  5.0  14.0  8.0   'SPEEDC'   11
1986  5  34.3  31.5  34.2  1.5  27.0  0.0   'DRVLUB'   2
```

1982	1	84.2	12.8	3.0	5.0	10.0	10.0	'MANODR'	6
1982	1	84.2	12.8	3.0	1.4	55.0	55.0	'RADIAL'	8
1983	2	84.4	12.7	2.9	1.5	7.0	0.0	'DRVLUB'	2
1983	2	84.4	12.7	2.9	5.0	3.0	0.0	'AUTODR'	5
1983	2	84.4	12.7	2.9	5.0	12.0	10.0	'MANODR'	6
1983	2	84.4	12.7	2.9	1.4	58.0	55.0	'RADIAL'	8
1984	3	84.5	12.7	2.8	1.5	13.0	0.0	'DRVLUB'	2
1984	3	84.5	12.7	2.8	5.0	6.0	0.0	'AUTODR'	5
1984	3	84.5	12.7	2.8	5.0	14.0	10.0	'MANODR'	6
1984	3	84.5	12.7	2.8	1.4	61.0	55.0	'RADIAL'	8
1985	4	84.6	12.7	2.7	1.5	20.0	0.0	'DRVLUB'	2
1985	4	84.6	12.7	2.7	5.0	10.0	0.0	'AUTODR'	5
1985	4	84.6	12.7	2.7	5.0	16.0	10.0	'MANODR'	6
1985	4	84.6	12.7	2.7	1.4	64.0	55.0	'RADIAL'	8
1986	5	84.8	12.7	2.5	1.5	27.0	0.0	'DRVLUB'	2
1986	5	84.8	12.7	2.5	5.0	13.0	0.0	'AUTODR'	5
1986	5	84.8	12.7	2.5	5.0	18.0	10.0	'MANODR'	6
1986	5	84.8	12.7	2.5	1.4	67.0	55.0	'RADIAL'	8

1982	1	84.2	14.4	1.4	5.0	10.0	10.0	'MANODR'	6
1982	1	84.2	14.4	1.4	1.4	55.0	55.0	'RADIAL'	8
1983	2	84.2	14.4	1.4	1.5	7.0	0.0	'DRVLUB'	2
1983	2	84.2	14.4	1.4	5.0	3.0	0.0	'AUTODR'	5
1983	2	84.2	14.4	1.4	5.0	12.0	10.0	'MANODR'	6
1983	2	84.2	14.4	1.4	1.4	58.0	55.0	'RADIAL'	8
1984	3	84.2	14.4	1.4	1.5	13.0	0.0	'DRVLUB'	2
1984	3	84.2	14.4	1.4	5.0	6.0	0.0	'AUTODR'	5
1984	3	84.2	14.4	1.4	5.0	14.0	10.0	'MANODR'	6
1984	3	84.2	14.4	1.4	1.4	61.0	55.0	'RADIAL'	8
1985	4	84.2	14.4	1.4	1.5	20.0	0.0	'DRVLUB'	2
1985	4	84.2	14.4	1.4	5.0	10.0	0.0	'AUTODR'	5
1985	4	84.2	14.4	1.4	5.0	16.0	10.0	'MANODR'	6
1985	4	84.2	14.4	1.4	1.4	64.0	55.0	'RADIAL'	8
1986	5	84.2	14.4	1.4	1.5	27.0	0.0	'DRVLUB'	2
1986	5	84.2	14.4	1.4	5.0	13.0	0.0	'AUTODR'	5
1986	5	84.2	14.4	1.4	5.0	18.0	10.0	'MANODR'	6
1986	5	84.2	14.4	1.4	1.4	67.0	55.0	'RADIAL'	8

1982	1	82.7	14.2	3.1	5.0	10.0	10.0	'MANODR'	6
1982	1	82.7	14.2	3.1	1.4	55.0	55.0	'RADIAL'	8
1983	2	82.7	14.2	3.1	1.5	7.0	0.0	'DRVLUB'	2
1983	2	82.7	14.2	3.1	5.0	3.0	0.0	'AUTODR'	5
1983	2	82.7	14.2	3.1	5.0	12.0	10.0	'MANODR'	6
1983	2	82.7	14.2	3.1	1.4	58.0	55.0	'RADIAL'	8
1984	3	82.7	14.2	3.1	1.5	13.0	0.0	'DRVLUB'	2
1984	3	82.7	14.2	3.1	5.0	6.0	0.0	'AUTODR'	5
1984	3	82.7	14.2	3.1	5.0	14.0	10.0	'MANODR'	6
1984	3	82.7	14.2	3.1	1.4	61.0	55.0	'RADIAL'	8
1985	4	82.7	14.2	3.1	1.5	20.0	0.0	'DRVLUB'	2
1985	4	82.7	14.2	3.1	5.0	10.0	0.0	'AUTODR'	5
1985	4	82.7	14.2	3.1	5.0	16.0	10.0	'MANODR'	6
1985	4	82.7	14.2	3.1	1.4	64.0	55.0	'RADIAL'	8
1986	5	82.7	14.2	3.1	1.5	27.0	0.0	'DRVLUB'	2
1986	5	82.7	14.2	3.1	5.0	13.0	0.0	'AUTODR'	5
1986	5	82.7	14.2	3.1	5.0	18.0	10.0	'MANODR'	6
1986	5	82.7	14.2	3.1	1.4	67.0	55.0	'RADIAL'	8

1982	1	83.2	14.8	2.0	2.5	5.0	5.0	'AERO'	4
1982	1	83.2	14.8	2.0	1.0	14.0	14.0	'RADIAL'	8
1982	1	83.2	14.8	2.0	3.3	50.0	50.0	'FANDRV'	10
1982	1	83.2	14.8	2.0	3.0	4.0	4.0	'SPEEDC'	11
1982	1	83.2	14.8	2.0	3.0	5.0	5.0	'AERO'	4
1983	1	84.7	13.7	1.6	2.5	5.0	14.0	'RADIAL'	8
1983	1	84.7	13.7	1.6	1.0	14.0	0.0	'DRVLUB'	2
1983	1	84.7	13.7	1.6	1.3	7.0	0.0	'ADVRAD'	9
1983	1	84.7	13.7	1.6	3.0	1.0	50.0	'FANDRV'	10
1983	1	84.7	13.7	1.6	3.3	50.0	4.0	'SPEEDC'	11
1983	1	84.7	13.7	1.6	3.0	4.0	5.0	'AERO'	4
1984	1	83.6	14.8	1.9	2.5	5.0	14.0	'RADIAL'	8
1984	1	83.6	14.8	1.9	1.0	14.0	0.0	'ADVRAD'	9
1984	1	83.6	14.8	1.9	3.0	2.0	0.0	'DRVLUB'	2
1984	1	83.6	14.8	1.9	1.3	7.0	50.0	'FANDRV'	10
1984	1	83.6	14.8	1.9	3.0	70.0	4.0	'SPEEDC'	11
1984	1	83.6	14.8	1.9	3.0	4.0	5.0	'AERO'	4
1985	1	85.2	13.4	1.4	2.5	5.0	14.0	'RADIAL'	8
1985	1	85.2	13.4	1.4	1.0	14.0	0.0	'ADVRAD'	9
1985	1	85.2	13.4	1.4	3.0	2.0	0.0	'DRVLUB'	2
1985	1	85.2	13.4	1.4	1.3	7.0	0.0	'SPEEDC'	11
1985	1	85.2	13.4	1.4	3.0	30.0	50.0	'FANDRV'	10
1985	1	85.2	13.4	1.4	3.3	30.0	5.0	'AERO'	4
1986	5	84.7	13.7	1.6	2.5	5.0	14.0	'RADIAL'	8
1986	5	84.7	13.7	1.6	3.0	14.0	4.0	'ADVRAD'	9
1986	5	84.7	13.7	1.6	0.0	4.0	0.0	'DRVLUB'	2
1986	5	84.7	13.7	1.6	1.5	27.0	0.0	'SPEEDC'	11
1986	5	84.7	13.7	1.6	0.0	5.0	4.0	'FANDRV'	10
1986	5	84.7	13.7	1.6	5.3	60.0	50.0	'FANDRV'	10

1982	1	88.6	10.1	1.3	5.0	10.0	10.0	'MANODR'	6
1982	1	88.6	10.1	1.3	1.4	55.0	55.0	'RADIAL'	8
1983	2	88.6	10.1	1.3	1.5	7.0	0.0	'DRVLUB'	2
1983	2	88.6	10.1	1.3	5.0	3.0	0.0	'AUTODR'	5
1983	2	88.6	10.1	1.3	5.0	12.0	10.0	'MANODR'	6
1983	2	88.6	10.1	1.3	1.4	58.0	55.0	'RADIAL'	8
1984	3	88.6	10.1	1.3	1.5	13.0	0.0	'DRVLUB'	2
1984	3	88.6	10.1	1.3	5.0	6.0	0.0	'AUTODR'	5
1984	3	88.6	10.1	1.3	5.0	14.0	10.0	'MANODR'	6
1984	3	88.6	10.1	1.3	1.4	61.0	55.0	'RADIAL'	8
1985	4	88.6	10.1	1.3	1.5	20.0	0.0	'DRVLUB'	2
1985	4	88.6	10.1	1.3	5.0	10.0	0.0	'AUTODR'	5
1985	4	88.6	10.1	1.3	5.0	16.0	10.0	'MANODR'	6
1985	4	88.6	10.1	1.3	1.4	64.0	55.0	'RADIAL'	8
1986	5	88.6	10.1	1.3	1.5	27.0	0.0	'DRVLUB'	2
1986	5	88.6	10.1	1.3	5.0	13.0	0.0	'AUTODR'	5
1986	5	88.6	10.1	1.3	5.0	18.0	10.0	'MANODR'	6
1986	5	88.6	10.1	1.3	1.4	67.0	55.0	'RADIAL'	8

1982	1	98.4	1.6	0.0	2.5	5.0	5.0	'AERO'	4
1982	1	98.4	1.6	0.0	3.0	14.0	14.0	'RADIAL'	8
1982	1	98.4	1.6	0.0	5.3	50.0	50.0	'FANDRV'	10
1982	1	98.4	1.6	0.0	6.0	4.0	4.0	'SPEEDC'	11
1982	1	98.4	1.6	0.0	2.5	5.0	5.0	'AERO'	4
1983	2	99.7	0.3	0.0	3.0	14.0	14.0	'RADIAL'	8
1983	2	99.7	0.3	0.0	1.5	7.0	0.0	'DRVLUB'	2
1983	2	99.7	0.3	0.0	6.0	1.0	0.0	'ADVRAD'	9
1983	2	99.7	0.3	0.0	5.3	60.0	50.0	'FANDRV'	10
1983	2	99.7	0.3	0.0	6.0	4.0	4.0	'SPEEDC'	11
1983	2	99.7	0.3	0.0	2.5	5.0	5.0	'AERO'	4
1984	3	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1984	3	100.0	0.0	0.0	6.0	2.0	0.0	'ADVRAD'	9
1984	3	100.0	0.0	0.0	1.5	13.0	0.0	'DRVLUB'	2
1984	3	100.0	0.0	0.0	5.3	70.0	50.0	'FANDRV'	10
1984	3	100.0	0.0	0.0	6.0	4.0	4.0	'SPEEDC'	11
1984	3	100.0	0.0	0.0	2.5	5.0	5.0	'AERO'	4
1985	4	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1985	4	100.0	0.0	0.0	6.0	3.0	0.0	'ADVRAD'	9
1985	4	100.0	0.0	0.0	1.5	20.0	0.0	'DRVLUB'	2
1985	4	100.0	0.0	0.0	5.3	80.0	50.0	'FANDRV'	10
1985	4	100.0	0.0	0.0	6.0	5.0	4.0	'SPEEDC'	11
1985	4	100.0	0.0	0.0	2.5	7.0	5.0	'AERO'	4
1986	5	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1986	5	100.0	0.0	0.0	6.0	4.0	0.0	'ADVRAD'	9
1986	5	100.0	0.0	0.0	1.5	27.0	0.0	'DRVLUB'	2
1986	5	100.0	0.0	0.0	6.0	5.0	4.0	'SPEEDC'	11
1986	5	100.0	0.0	0.0	5.3	90.0	50.0	'FANDRV'	10

1982	1	100.0	0.0	0.0	2.5	5.0	5.0	'AERO'	4
1982	1	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1982	1	100.0	0.0	0.0	5.3	50.0	50.0	'FANDRV'	10
1982	1	100.0	0.0	0.0	6.0	4.0	4.0	'SPEEDC'	11
1983	2	100.0	0.0	0.0	2.5	5.0	5.0	'AERO'	4
1983	2	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1983	2	100.0	0.0	0.0	1.5	7.0	0.0	'DRVLUB'	2
1983	2	100.0	0.0	0.0	6.0	1.0	0.0	'ADVRAD'	9
1983	2	100.0	0.0	0.0	5.3	50.0	50.0	'FANDRV'	10
1983	2	100.0	0.0	0.0	6.0	4.0	4.0	'SPEEDC'	11
1984	3	100.0	0.0	0.0	2.5	5.0	5.0	'AERO'	4
1984	3	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1984	3	100.0	0.0	0.0	6.0	2.0	0.0	'ADVRAD'	9
1984	3	100.0	0.0	0.0	1.5	13.0	0.0	'DRVLUB'	2
1984	3	100.0	0.0	0.0	5.3	70.0	50.0	'FANDRV'	10
1984	3	100.0	0.0	0.0	6.0	4.0	4.0	'SPEEDC'	11
1985	4	100.0	0.0	0.0	2.5	6.0	5.0	'AERO'	4
1985	4	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1985	4	100.0	0.0	0.0	6.0	3.0	0.0	'ADVRAD'	9
1985	4	100.0	0.0	0.0	1.5	20.0	0.0	'DRVLUB'	2
1985	4	100.0	0.0	0.0	6.0	5.0	4.0	'SPEEDC'	11
1985	4	100.0	0.0	0.0	5.3	80.0	50.0	'FANDRV'	10
1986	5	100.0	0.0	0.0	2.5	7.0	5.0	'AERO'	4
1986	5	100.0	0.0	0.0	3.0	14.0	14.0	'RADIAL'	8
1986	5	100.0	0.0	0.0	6.0	4.0	0.0	'ADVRAD'	9
1986	5	100.0	0.0	0.0	1.5	27.0	0.0	'DRVLUB'	2
1986	5	100.0	0.0	0.0	6.0	5.0	4.0	'SPEEDC'	11
1986	5	100.0	0.0	0.0	5.3	90.0	50.0	'FANDRV'	10